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## FISHERY DEVELOPMENT AND MANAGEMENT IN THAILAND

by

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# FISHERY DEVELOPMENT AND MANAGEMENT IN THAILAND


## Abstract

After a period of stabilization lasting more than 20 years, the Thai sea fisheries developed rapidly during the past decade through the introduction of trawl fishing. Suitable nets and fishing techniques were demonstrated and introduced in the course of a German bilateral aid project. This new input, together with a high level of technical abilities among the fishermen, the availability of sufficient capital to finance a trawler fleet of more than 2 500 boats and adequate support from the Thai Government, resulted in a rapid development of trawling from small vessels. Landings were about 600 000 metric tons of groundfish from the coastal area in 1970. About half of this is for human consumption, the remainder mostly being used fresh for duck food or, after processing, as chicken food. The level of development achieved has unfortunately meant that the moderately rich bottom-fish resources of the Gulf of Thailand have become overexploited. In 1971 the catch per unit of effort had decreased to only a quarter of the original, making trawling operations only marginally economic. This points up the difficult problem of the control of fishing effort, which the Government of Thailand, no less than other nations, has not yet been able to resolve satisfactorily.


# DEVELOPPEMENT ET AMENAGEMENT DES PECHES EN THAILANDE


## Résumé

Après une période de stagnation de plus de vingt ans, les pêcheries maritimes de la Thaïlande ont pris un rapide essor au cours de la dernière décennie grâce à l'introduction de la pêche au chalut. Des filets et des techniques de pêche modernes ont fait l'objet de démonstrations et ont été adoptées dans le cadre d'un projet allemand d'aide bilatérale. Cette contribution, joint à un niveau élevé de compétence technique parmi les pêcheurs, à la disponibilité de capitaux suffisants pour financer une flottille de plus de 2 500 chalutiers et à l'appui dynamique du Gouvernement thaïlandais, a abouti à un rapide essor du petit chalutage. Les quantités débarquées ont atteint approximativement 600 000 tonnes métriques de poisson de fond pour la zone côtière en 1970. La moitié environ est destinée à la consommation humaine, le reste étant essentiellement utilisé à l'état frais pour l'alimentation des canards ou, après traitement, pour l'alimentation des poulets. Un tel stade de développement signifie malheureusement que les ressources médiocres en poissons de fond du golfe du Siam sont surexploitées. En 1971, les prises par unité d'effort sont tombées à un quart seulement de ce qu'elles étaient à l'origine, les opérations de chalutage se trouvant ainsi n'avoir plus qu'une importance économique marginale. Cela tend à démontrer combien il est difficile de contrôler l'effort de pêche - difficulté que le Gouvernement de la Thaïlande, pas plus que d'autres nations, n'a été en mesure de résoudre de façon satisfaisante.


# USO Y REGLAMENTACION DE LA PESCA EN TAILANDIA


## Extracto

Después de un período de estabilidad que ha durado más de 20 años, en Tailandia, la pesca oceánica ha aumentado rápidamente durante el pasado decenio con la iniciación de la pesca de arrastre. En el curso de un proyecto alemán de ayuda bilateral se hicieron demostraciones de redes y de técnicas de pesca, que más adelante se llevaron a la práctica. Estas innovaciones, junto con una mayor capacidad técnica de los pescadores, disponibilidad de capital suficiente para financiar una flota de arrastreros compuesta por más de embarcaciones y la ayuda por parte del Gobierno de Tailandia, dió por resultado un rápido incremento de la pesca de arrastre realizada con barcos pequeños. En 1970 se descargaron

unos 600 000 toneladas métricas de especies demersales costeras. La mitad de esta cantidad se destina al consumo humano y el resto se emplea principalmente en fresco para la alimentación de patos o, después de tratado, como pienso para aves de corral. Desgraciadamente el perfeccionamiento logrado ha significado que los recursos demersales del Golfo de Tailandia, que eran moderadamente ricos, hayan sido superexplotados. En 1971 las capturas por unidad de esfuerzo habían disminuido a sólo un tercio de las originales, por lo que la explotación con arrastreros constituía una actividad de poca importancia económica. Ello demuestra lo difícil de reglamentar la intensidad de la pesca que el Gobierno de Tailandia, como sucede con otras naciones, aún no ha podido resolver satisfactoriamente.

## 1 INTRODUCTION

Thailand, covering about 514 000 km$^2$ and having a population of some 35 million, is located between 6°-20°N in a zone of tropical monsoon climate with water temperatures around 28°C. The country has undergone one of the most exciting fisheries developments in the world during the last decade, after its relatively modest fisheries landings had changed little for more than 20 years. According to the FAO Yearbook of Fisheries Statistics (13) its marine fisheries production has risen from 150 000 metric tons in 1960 to 1.5 million tons in 1970 (Table 1), and although the accuracy of both estimates is doubtful, there is no question that Thai fisheries have developed tremendously during the past decade. The author has been invited to prepare this paper since he has advised the Thai Government on fisheries matters from time to time since 1958, and since he has been supervising a German bilateral fisheries aid project in Thailand from his Hamburg office since 1961 (44-49).

Table 1. Mean annual fisheries yield in Thailand for 1955-60

| | |
|---|---|
| Marine fisheries: | |
| Mackerels | 40.0 |
| Sharks | 2.7 |
| Miscellaneous fish | 37.3 |
| Shrimps and crabs | 13.0 |
| Molluscs | 55.2 |
| Total: | 152.2 |
| Freshwater fisheries: | |
| Air-breathers | 23.1 |
| Carps | 7.9 |
| Miscellaneous fish | 27.1 |
| Prawns | 3.8 |
| Total: | 61.9 |
| Grand Total: | 214.1 |

## 2 FISHERIES UP TO 1960

Even before 1960 Thailand could be considered a fishing nation. Throughout its recorded history the people have fished their rivers, canals, swamps, paddy-fields and seas. At that time the fisheries were largely subsistence enterprises, which occasionally sold fish and fish products on the retail markets, or hawked them from house to house. So, more than 32 000 professional fishermen were available in 1960 (10, 44).

There was a well established marine fishery using 1 590 motorized fishing vessels having a total of 18 300 gross tons and 1 440 unmotorized boats, totalling 9 800 gross tons. Most of these units were small planked boats 10-14 m long, but some 200 purse

seine boats were 16-20 m long and were equipped with engines having 50-120 HP. This means that shipbuilding was already a well established industry. Wooden cargo ships were being built of even larger sizes (44).

Thailand was not only a fishing nation, but also a nation of fish-eaters. Among sea fishes, the Indo-Pacific chub mackerel (Rastrelliger) was preferred, and in some coastal areas one of the world's highest annual fish consumption rates prevailed - 70 kg per caput.

A great variety of fishing gear was in use, showing that Thai fishermen were always very responsive to new developments. The most important gears were cotton purse seines, bamboo fish corrals (stake traps) operated in coastal waters, and nylon gillnets. All other gears, such as hand lines and trolling lines, longlines, liftnets, castnets, pushnets, beach seines and spears, were of minor importance.

The smoothly-functioning Bangkok Fish Marketing Organization was established in 1953. During the past decade several landing ports of various sizes have been constructed in major fish landing areas along the coast of the Thai Gulf and on the western sea coast of Thailand. At present there are 26 landing quays and jetties in the country. Among these 11 are of medium or large size and were constructed using governmental budget appropriations, the other 15 were constructed using fishery promotion funds set aside from the money collected as service charges in the operation of the Bangkok Fish Terminal, with supporting funds from private sources (34).

Until 1960, of the two large resources accessible to the Thai fishermen, i.e., the pelagic and the bottom fishes, only the pelagic resource, mainly chub mackerel (Rastrelliger) was well known to the Thai fishing industry or administration, and for practical purposes it was the only one utilized. During the years from 1938 to 1960 the Thai fishing industry - because of its unfamiliarity with the much larger bottom-fish resource - was more or less stagnant. Annual landings varied between 161 000 tons (1938) and 233 000 tons (1957). For 1955-60 the annual average catch was 214 000 tons, of which 152 200 tons came from the marine fisheries (Table 1) and the rest from inland fisheries (44).

During this period the most important branch of the Thai marine fishery from the economic point of view was the chub mackerel or pla thu fishery, mostly carried out by means of purse seines but also by bamboo traps. Even larger yields were obtained from harvesting mussel beds, mainly of Mytilus smaragdinus. The other third of the landings of the marine fisheries consisted of a great variety of species, among which crustaceans (crab and shrimps) played an important role.

## 3 STEPS TAKEN FOR DEVELOPMENT

When I looked at the fisheries situation in Thailand during my first visit to the country in 1958, it seemed obvious that further development of the sea fisheries would have to be focused on the exploitation of other resources, because utilization of the pelagic resource was already far advanced. I therefore recommended to the Government that it should be determined whether the sea fisheries could be expanded by introducing a trawl fishery. Since previous attempts to introduce this type of fishery in the Gulf of Thailand, in 1926 and in 1955-56, had failed (47), the Thai Government asked the Government of the Federal Republic of Germany to render assistance under a bilateral aid project, which has been in operation since 1961. The project was to develop a trawlnet suitable for local needs; to investigate whether demersal fish stocks were abundant enough to support a commercial trawl fishery; to assess the distribution and size of trawlable stocks; to demonstrate fishing techniques to the local industry; to assess changes in the demersal fish stocks in the course of the development of a commercial trawl fishery; to train counterpart assistants of the Thai Department of Fisheries in fisheries research along these lines; and to advise the Government on management.

As is known and well documented (44-49), the project has had a great impact on the stormy development of trawl fisheries in Thailand, for it has fulfilled most of its goals.

Within the first 4 weeks, a suitable otter board trawlnet was developed (44) (Fig. 1), known as the "Engel trawl" (after the master net-maker Hans-Hermann Engel Jr.) or "Thai trawl". It has since been used in many other countries. Its effectiveness was demonstrated using a wooden 23-metre stern trawler (225 HP) of the fishing industry. After this simple stern-trawling method was introduced, training fishermen became very easy; it could be done without any sophisticated training programme, simply by holding 2- or 3-day training courses in a large number of fishing villages, in which the construction and repair of trawlnets and trawl fishing were demonstrated. The Thai fishermen grasped the techniques involved in a very short time (45-46).

The economic success of the fishing technique introduced was sufficient to stimulate its wide use. This was made easier because consumers accepted trawl fish rather readily.

The German bilateral aid project was carried out as follows:

Phase 1 (1961): Basic investigations on the possibilities of an introduction of a trawl fishery in the Gulf of Thailand; development of a suitable trawlnet with special reference to the bottom structure of the Gulf and the trawlable fish stocks (German experts: 1 fisheries biologist (Dr. K. Tiews), 1 masterfisherman (Capt. F. Eggers Sr.), 1 master net-maker (H.H. Engel)) (45).

Phase 2 (1962-64): Introduction of the trawl fishery by demonstrations; holding numerous short-term training courses in fishing villages; distribution of construction plans for nets suitable for different sizes of fishing vessels; advice on fishing-boat construction; first complete assessment of trawl-fish resources (German experts: 1 masterfisherman (Capt. F. Eggers Sr.), 1 master net-maker (H.H. Engel)).

Phase 3 (1966-71): Equipping the Marine Fisheries Research Laboratory in Bangkok; performing research on the biological basis for a proper exploitation of the fish stocks in the Gulf of Thailand; advice on management aspects; (German experts: 1 fisheries biologist (Dr. G. Kühlmorgen-Hille), 1 masterfisherman (Capt. F. Eggers Sr. or Capt. F. Eggers Jr.)).

Phase 4 (1972 to at least 1975): Partnership arrangement between the Marine Fisheries Laboratory in Bangkok and the Federal Fisheries Research Institute (Bundesforschungsanstalt für Fischerei) in Hamburg to provide short-term advice in the fields of stock assessment and management, marine pollution, aquaculture, taxonomy, fishing gear development, deep-sea trawling, etc. (German experts: various short-term experts in their fields (Mrs. Dr. E. Huschenbeth, Dr. W. Klausewitz, etc.)).

During the entire period these activities were accompanied by a scholarship programme, under which 11 Thai scientists have been trained in the Bundesforschungsanstalt für Fischerei in Hamburg and in other institutes in Germany since 1962.

Since the Thai Department of Fisheries recognized from the very beginning the great importance which a proper research programme could play in the development of fisheries, it made much effort to build up an adequate research service, in which today more than 60 scientists are employed. It also acquired 8 research vessels, among which the R/V DHANRAJATA is of 388 gross tons and 1 000 HP, while the other boats, except for one steel boat, are wooden and of cutter size and comparable with commercial fishing boats. Most of the research vessels were purposely built like fishing cutters in order to make the results obtained during exploratory fishing curises directly comparable with commercial fishing boats (42). Under the very effective leadership of the Director-General of the Department of Fisheries, Mr. Prida Karnasut, all financial and other necessary support was obtained.

## 4 THE BOTTOM FISH RESOURCE

The available bottom-fish resources consist of 150-200 or more species belonging to a great number of fish families (Table 3). Among the most abundant fish stocks are members of the Leiognathidae (9 species), Nemipteridae (10), Synodontidae (6), Carangidae (9),

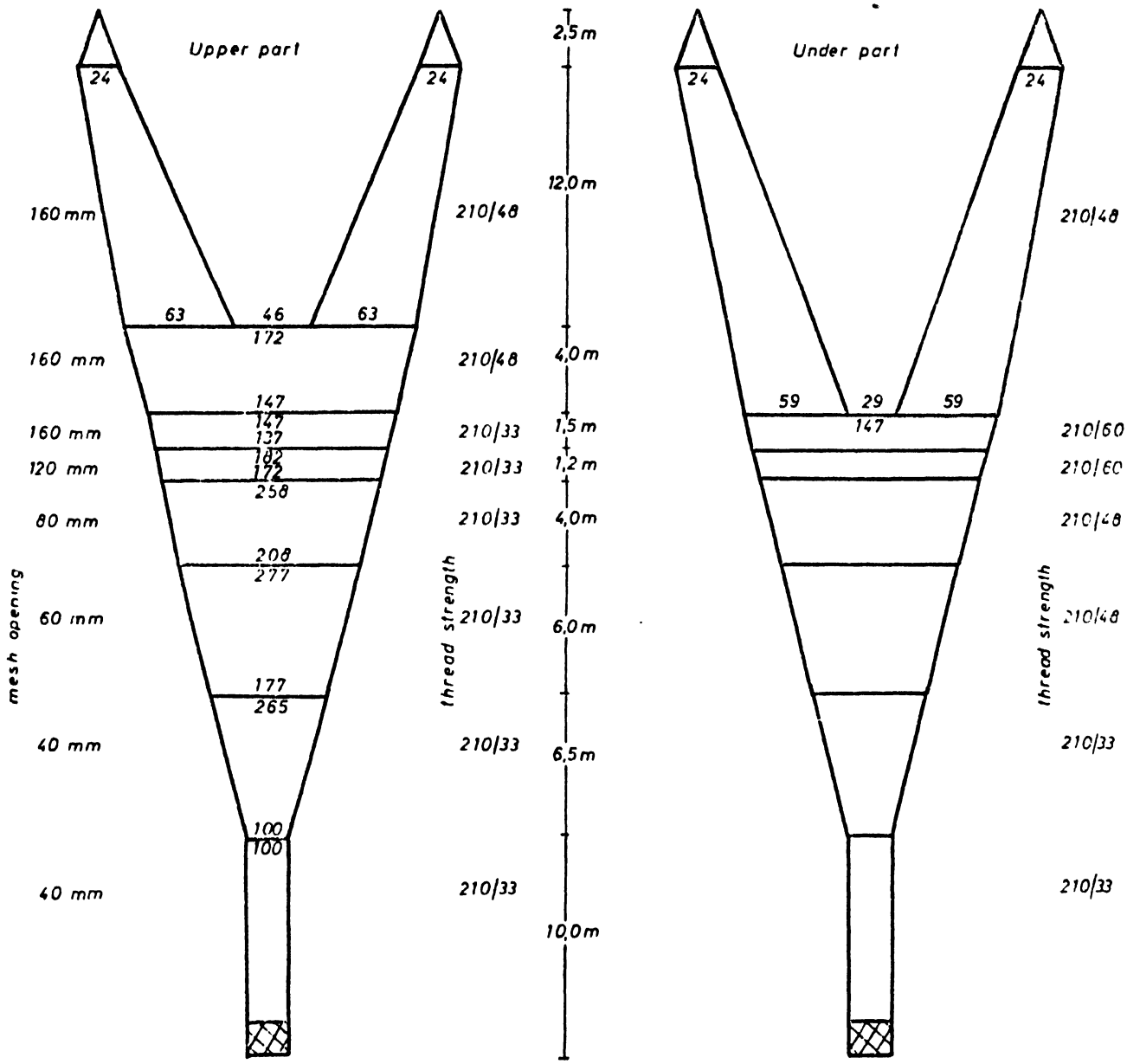


**Fig. 1 Standard otter board trawl used (the thread strength is given, according to international standards, in denier)**

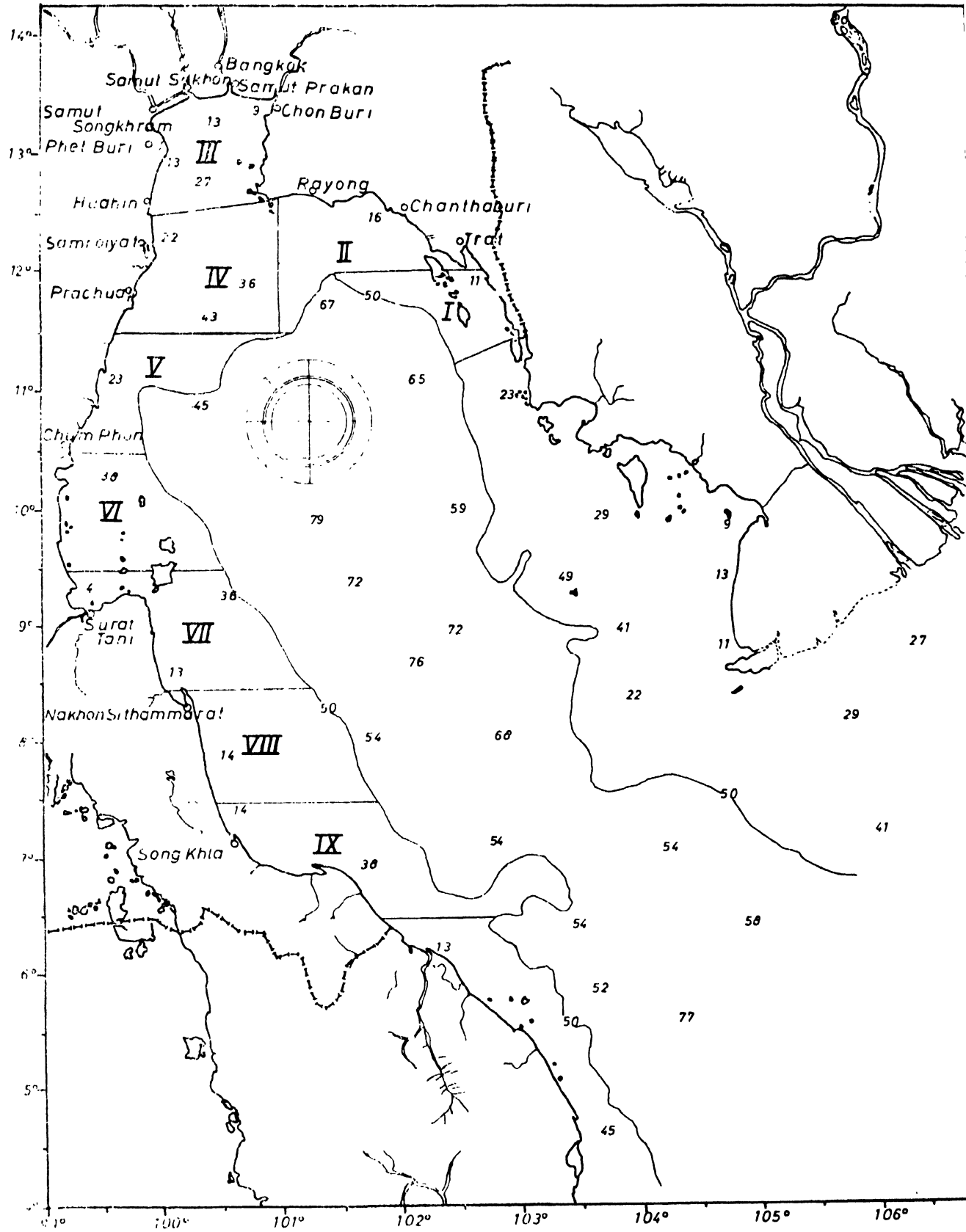


Fig. 2 Location of research areas I-IX in the Gulf of Thailand (soundings are in metres)

Sciaenidae (10), Lutjanidae (6), Trichiuridae (1), Priacanthidae (2), Plectorhynchidae (1) and Tachysuridae (3) (45, 58). Generally, it can be said that the number of species in the Gulf of Thailand increases from north to south. Several species reach their northern most limit of distribution on the Gulf coast of the Malay Peninsula between 6° and 7°N. On the east coast of the Gulf, however, they go as far as 12°N, probably because of a tongue of water with higher salinity extending north along this coast.

In order to assess the size of fish stocks, one of the Thai research cutters (R/V PRAMONG 2; 23 m, 320 HP) is systematically surveying year by year the entire coastal waters of Thailand, which were divided for this purpose into nine subareas (Fig. 2). It uses the standardized trawlnet described by Tiews (44) (Fig. 1). Between 700 and 800 fisheries stations are being covered annually. In the beginning these surveys had the objective of discovering new fishing grounds but now their function is to study changes in abundance that have parallelled the development of the commercial fishery. Since the research cutter is of the same dimension as many of the commercial fishing boats, these sets of data reflect nicely the trend to be expected also in the commercial fisheries (11, 25, 33, 37, 39, 45, 49).

At the beginning of the trawl fishery, trawlers of about 22 metres fishing only during daytime could easily produce 40 metric tons of fish worth 16 000 German Marks per month (45). If these trawlers had fished day and night, as was done later, a catch of 60 tons per month could easily have been obtained.

At that time the average catch per hour amounted to some 250–300 kg during the day. By 1971 the catch had decreased to 66 kg/hour, and in one area even as low as 30 kg/hour (Tables 2 and 3). The decline was not uniform for all species. The catch of a few species actually increased, for example, squid catches up to 1969, catches of Priacanthus, and especially those of Rastrelliger up to 1970.

Table 2. Average catch of demersal fish in kilogrammes per hour in the Gulf of Thailand made by the R/V PRAMONG 2 trawling survey in 1963 and in 1966–71. Data for 1963 are from Tiews (1965); data for 1966–71 are from the Demersal Fisheries Investigation Unit of the Marine Fisheries Research Laboratory at Bangkok

| Area | Year | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1963 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 |
| I | 340 | 113 | 107 | 66 | 57 | 82 | 33 |
| II | 230 | 58 | 41 | 54 | 64 | 49 | 30 |
| III | 264 | 109 | 95 | 68 | 74 | 52 | 46 |
| IV | 260 | 153 | 86 | 72 | 90 | 96 | 70 |
| V | 201 | 139 | 151 | 100 | 122 | 122 | 87 |
| VI | 286 | 137 | 90 | 187 | 114 | 99 | 76 |
| VII | 190 | 121 | 101 | 93 | 113 | 130 | 97 |
| VIII | 247 | 183 | 182 | 172 | 148 | 130 | 75 |
| IX | 212 | 165 | 180 | 142 | 149 | 117 | 82 |
| | 249 | 131 | 115 | 106 | 103 | 97 | 66 |

Table 3. Catch composition by year in kilogrammes per hour of trawling by R/V PRAMONG 2 throughout the Gulf of Thailand (Areas I-IX)

| Group of fish | Year | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1963 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 |
| 1. Sharks | 2.1 | 1.86 | 1.64 | 1.04 | 0.60 | 0.75 | 0.60 |
| 2. Rhinobatidae | - | 0.62 | 0.65 | 0.84 | 0.43 | 0.40 | 0.48 |
| 3. Rays | 14.8 | 9.63 | 4.77 | 2.17 | 2.99 | 2.86 | 1.35 |
| 4. Anodontostoma spp. | - | 0.24 | 0.15 | 0.30 | 0.36 | 0.21 | 0.11 |
| 5. Chirocentrus spp. | 0.2 | 0.19 | 0.13 | 0.30 | 0.17 | 0.23 | 0.14 |
| 6. Saurida spp. | 11.3 | 5.34 | 4.52 | 5.42 | 5.29 | 6.64 | 3.06 |
| 7. Tachysuridae | 7.4 | 3.39 | 2.14 | 1.79 | 1.31 | 1.44 | 0.98 |
| 8. Muraenesox spp. | 0.1 | 0.24 | 0.16 | 0.21 | 0.66 | 0.26 | 0.28 |
| 9. Sphyraena spp. | 2.1 | 1.74 | 1.37 | 0.74 | 1.14 | 1.43 | 0.35 |
| 10. Serranidae | 0.8 | 1.23 | 1.37 | 1.05 | 0.95 | 0.86 | 0.51 |
| 11. Priacanthus spp. | 5.6 | 4.08 | 7.17 | 6.22 | 7.45 | 7.38 | 5.21 |
| 12. Sillago spp. | - | - | - | - | - | 0.04 | 0.01 |
| 13. Lactarius lactarius | 0.6 | 0.59 | 0.19 | 0.23 | 0.10 | 0.02 | 0.03 |
| 14. Carangidae | 19.7 | 9.89 | 9.11 | 9.90 | 9.25 | 9.08 | 3.89 |
| 15. Rachycentron canadus | 0.2 | 0.24 | 0.33 | 0.23 | 0.21 | 0.22 | 0.09 |
| 16. Lutjanidae | 1.5 | 4.76 | 4.02 | 3.83 | 3.01 | 2.25 | 0.99 |
| 17. Nemipterus spp. | 18.4 | 15.31 | 11.78 | 7.46 | 7.40 | 8.61 | 7.30 |
| 18. Gerridae | - | - | 5.93 | 3.13 | 3.06 | 2.55 | 1.48 |
| 19. Leiognathidae | 71.5 | 20.02 | 10.87 | 14.37 | 10.59 | 10.25 | 2.98 |
| 20. Pomadasys spp. | 0.4 | 0.41 | 0.32 | 0.21 | 0.30 | 0.16 | 0.05 |
| 21. Scolopsis spp. | 7.6 | 4.74 | 3.28 | 2.63 | 3.91 | 2.82 | 1.91 |
| 22. Plectorhynchidae | 1.3 | 1.17 | 1.37 | 0.95 | 1.09 | 0.63 | 0.23 |
| 23. Sciaenidae | 18.3 | 2.60 | 4.54 | 2.68 | 0.63 | 1.46 | 0.61 |
| 24. Lethrinidae | 0.2 | 0.47 | 0.86 | 0.33 | 0.28 | 0.25 | 0.11 |
| 25. Mullidae | 16.1 | 5.90 | 9.74 | 7.24 | 6.14 | 3.77 | 2.74 |
| 26. Trichiurus haumela | 0.9 | 1.01 | 1.24 | 1.46 | 0.74 | 0.94 | 0.69 |
| 27. Rastrelliger kanagurta | - | 0.42 | 0.66 | 0.63 | 0.96 | 0.86 | 0.47 |
| 28. Rastrelliger neglectus | 0.8 | 0.19 | 0.37 | 0.52 | 1.03 | 1.54 | 0.40 |
| 29. Scomberomorus spp. | 0.4 | 0.61 | 0.47 | 0.82 | 1.08 | 0.56 | 0.33 |
| 30. Pampus spp. | 0.4 | 0.27 | 0.16 | 0.19 | 0.13 | 0.09 | 0.06 |
| 31. Parastromateus niger | - | - | 0.21 | 0.38 | 0.37 | 0.51 | 0.20 |
| 32. Psettodes erumei | 0.4 | 0.99 | 0.63 | 0.58 | 0.65 | 0.56 | 0.71 |
| 33. Bothidae | - | 0.63 | 0.33 | 0.38 | 0.35 | 0.32 | 0.52 |
| 34. Cynoglossidae | - | 0.12 | 0.06 | 0.04 | 0.14 | 0.07 | 0.24 |
| 35. Sepia spp. | - | 2.80 | 1.87 | 2.10 | 2.33 | 2.62 | 2.28 |
| 36. Loligo spp. | 6.1 | 8.04 | 9.13 | 10.60 | 11.61 | 8.55 | 11.02 |
| 37. Thenus spp. | 2.0 | 0.72 | 0.34 | 0.35 | 0.29 | 0.19 | 0.13 |
| 38. Shrimps | 0.6 | 0.27 | 0.12 | 0.09 | 0.11 | 0.15 | 0.26 |
| 39. Crabs | 0.7 | 0.92 | 0.61 | 0.70 | 0.86 | 1.32 | 1.15 |
| 40. Caesio | - | 0.06 | 0.07 | 0.06 | 0.09 | - | - |
| Good fish | 220.1 | 111.71 | 102.67 | 92.19 | 88.06 | 82.85 | 53.95 |
| Scrap fish | 28.9 | 19.06 | 12.37 | 13.73 | 14.68 | 14.59 | 12.30 |
| Total: | 249.0 | 130.77 | 115.04 | 105.92 | 102.74 | 97.44 | 66.25 |

In the beginning (1960-61) it was found that the catch decreased with water depth. Highest catches were obtained at depths between 20 and 29 m (44). With the fishing-out of the inshore resources, however, the picture became reversed during the years 1966-70 (Table 4). Catches at depths greater than 50 m are too small to be called economic (45). The fishery is therefore more or less restricted to the shallower waters.

Table 4. Average catch of demersal fish in kilogrammes per hour by depth of water throughout the Gulf of Thailand from 1966 to 1970

| Year | Depth of water in metres | | | | |
|---|---|---|---|---|---|
| | 10-19 | 20-30 | 31-44 | 44+ | 10-44+ |
| 1966 | 107.19 | 127.51 | 144.72 | 134.80 | 130.77 |
| 1967 | 95.15 | 85.25 | 131.45 | 180.65 | 115.05 |
| 1968 | 88.96 | 98.99 | 109.16 | 131.66 | 105.92 |
| 1969 | 94.83 | 91.86 | 112.79 | 126.64 | 102.74 |
| 1970 | 102.76 | 82.68 | 110.92 | 103.00 | 97.44 |

There are roughly 31 500 square nautical miles of trawlable grounds along the entire Thai coast, including that facing the Andaman Sea. Tiews (47) estimated that this area would be suitable for an annual fish production of 390 000 tons. This estimate was based on an average production of 36 kg/hectare. Gulland (16) estimated the potential yield along the Thai coast of the Gulf of Thailand alone to be 400 000 tons.

Fifty percent of the trawl catches in the Gulf of Thailand consist of fish species which are mostly not being used at present for human consumption because of their small individual size, although such fish are tasty and are eaten by many people. In general, many species of this tropical resource attain only a small size. Although the numerical strength of the populations of these species is similar to that of the great populations of temperate waters, the yield by weight is much smaller. Nevertheless, the yield of the total resource, which consists of numerous fish species, might be as large as that from temperate waters. In general, these tropical species reach maturity more quickly than those of temperate waters, which might explain the fact that they are generally smaller than those of temperate waters (8, 22, 23, 28, 29, 45, 47, 50-56).

Fish rejected for human consumption because of small size are used fresh as duck food or, after processing into fish meal, as chicken food. Duck farming profited greatly from the development of the trawl fisheries and it has become one of the major food industries in the country.

## 5 FISHERY DEVELOPMENT SINCE 1960

It appears that the Thai fishing industry was just waiting for the discovery of a new unexploited resource. Consequently, it rushed into commercial utilization of the resource at a speed which is without example in the region. As seen from Table 5, the landings increased from year to year. One has, however, to look critically at these nominal catch statistics because errors of the statistical system are likely, especially during recent years. This is apparent from a comparison of the reliable research data showing the change in catch per unit of effort (Tables 2 and 3) with the fleet statistics (Table 6) and the catch statistics (Table 5). It is difficult to estimate the error in the catch statistics (although this is attempted below) because the fleet statistics too may be incomplete and because large parts of the fleet might have engaged in distant-water fishing outside the research areas from which catch-per-unit-effort data were collected.

Table 5. Estimated annual catches of Thailand, 1958-67, in thousands of metric tons

| Group of species | Year | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1958 | 1959 | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 |
| Marine: | | | | | | | | | | | | | |
| Mackerels | 44.3 | 36.1 | 29.9 | 23.2 | 36.0 | 23.3 | 52.5 | 69.9 | 87.8 | 30.9 | 148.1 | 131.9 | 139.6 |
| Sharks and rays | 2.7 | 2.8 | 4.3 | 4.0 | 4.5 | 5.1 | 5.8 | 7.4 | 6.8 | 8.0 | 12.3 | 18.8 | 26.0 |
| Other demersal fishes | 37.1 | 42.1 | 44.9 | 102.6 | 126.8 | 190.0 | 327.2 | 338.9 | 384.4 | 442.2 | 602.3 | 773.4 | 919.2 |
| Shrimps and Crabs | 10.3 | 13.5 | 14.5 | 16.5 | 20.2 | 32.5 | 38.7 | 46.3 | 57.3 | 75.1 | 99.2 | 91.2 | 132.2 |
| Molluscs | 50.6 | 53.2 | 52.8 | 87.0 | 82.2 | 72.4 | 40.0 | 66.9 | 98.8 | 105.7 | 141.8 | 164.4 | 266.5 |
| Total: | 145.0 | 147.7 | 146.4 | 233.3 | 269.7 | 323.3 | 494.1 | 529.4 | 635.1 | 761.9 | 1 003.7 | 1 179.7 | 1 483.5 |
| Freshwater: | | | | | | | | | | | | | |
| Air-breathers | 17.4 | 20.6 | 35.0 | 22.7 | 25.2 | 49.0 | 26.5 | 35.7 | 38.7 | 39.9 | - | - | - |
| Carps | 5.5 | 7.3 | 7.5 | 9.0 | 9.6 | 8.0 | 7.7 | 9.7 | 9.9 | 8.9 | 7.8 | 6.0 | 12.2 |
| Miscellaneous | 25.1 | 26.0 | 25.7 | 37.4 | 31.8 | 35.0 | 44.8 | 36.3 | 33.2 | 33.0 | 73.3 | 79.8 | 95.1 |
| Prawns | 3.3 | 3.1 | 4.4 | 3.3 | 3.5 | 3.4 | 3.8 | 4.0 | 3.3 | 3.7 | 4.0 | 4.1 | 4.3 |
| Total: | 51.3 | 57.0 | 72.6 | 72.4 | 70.1 | 95.4 | 82.8 | 85.7 | 85.1 | 85.5 | 85.1 | 89.9 | 111.6 |
| Total Catch: | 196.3 | 204.7 | 219.0 | 305.7 | 339.8 | 418.7 | 576.9 | 615.1 | 720.2 | 847.4 | 1 088.8 | 1 269.6 | 1 595.1 |

Table 6. Trawlers in use, 1967-70

| Year | Number of trawlers | | | Size of trawlers | | | |
|---|---|---|---|---|---|---|---|
| | Otter-board trawlers | Pair trawlers | Total | 25+ m | 18-24 m | 14-18 m | Less than 14 m |
| 1967 | 1 380 | 352 | 1 732 | 0 | 318 | 701 | 713 |
| 1968 | 2 258 | 488 | 2 746 | 0 | 575 | 1 188 | 983 |
| 1969 | 1 939 | 496 | 2 435 | 0 | 499 | 1 066 | 870 |
| 1970 | 2 230 | 454 | 2 684 | 67 | 644 | 1 172 | 801 |

The shipbuilding industry has also profited greatly from this boom. It has been estimated that some 94 shipyards were located in major coastal provinces in 1967 on both the Gulf of Thailand and Indian Ocean sides of the country. A majority of these shipyards (about 54) are located near Bangkok (34).

According to the first census of marine fisheries in Thailand in 1967, the total number of fishing craft that were in use then in marine fisheries was 35 631, of which 19 266 were power boats and 16 365 were non-powered boats.

As it was extremely difficult to make a complete enumeration of the number of boats employed by the subsistence-fishery households, only the number of trawlers used in the enterprise fisheries could be accurately censused. In 1967, 1 732 such trawlers were counted and in 1970 there were 2 684 (Table 6).

As Menasveta and Isarankura (34) have described for 1967, otter board trawlers of 10-15 m had on the average engines of some 50 HP, those of 15-20 m 90 HP, 20-25 m 200 HP, and 25-30 m 250 HP.

To cope with the landings, the Government helped greatly to improve landing facilities, as described above.

Recognizing the various shortcomings and the lack of proper knowledge on the part of Thai fishermen and fishermen of other developing countries in Southeast Asia, especially as regards navigation for distant-water fishing, the Thai Government has played a leading role in the establishment of the Southeast Asian Fisheries Development Centre, which has been in operation in Bangkok and in Singapore since 1969 (34). But even without such special training, Thai fishing boat captains had already been fishing off the coasts of Vietnam, Malaysia and Borneo.

Fisheries loans were set aside for fishermen to invest in marine fisheries as well as in fish culture (27). The main emphasis of governmental services to fisheries, however, is on rendering extension services to commercial fisheries to implement research findings concerning fishing, etc.

The rapid development has had several positive side-effects. First of all, many more jobs were created in the fishing and allied industries. The Thai Government also receives annually revenues from the income derived from business transactions in buying and selling fishery products, from catching through to retailing operations. The average amount received

by the Government is approximately 4.5 percent of the estimated value of landings. For example, in 1967 the Government had an income from the fisheries amounting to 153 million Baht or approximately U.S.$ 7.6 million. In addition the Government receives substantial revenues from allied industries, such as ice plants, fuel, fishing boats, net-making factories, etc. Other sources of Government income from fisheries are licensing of fishing gear (6 million Baht) and from exports of fisheries products (34).

## 6 NEED FOR MANAGEMENT OF THE TRAWL FISHERY

Tiews (44), when reporting on a first rough estimate of the size of trawlable fish stocks in the Gulf of Thailand, recommended in 1962 that as a careful step toward the development of a commercial trawl fishery one ought not to catch more than 75 000 metric tons annually, so as to be able to study carefully the effects of trawl fishing on the resource. It was also recommended that trawl fishing be developed gradually, by licensing not more than 10-20 new fishing boats for trawling every year. On the basis that one boat can annually land catches averaging 500 tons when fishing only by day, a total of not more than 150 boats would be needed to achieve the target of 75 000 metric tons of trawl fish per year. It was, however, wishful thinking to suppose that development could be steered along these lines. Instead, the very dynamic Thai fishing industry pressed into the new fishery with an unforeseen capital input, without regard to possible losses later on. Profits were so large that most of the fishing boats had been paid for in a few years. Although regrettable in the light of today's knowledge, one can certainly understand that the Thai Government was not enthusiastic about putting the brakes on this development, even if it had been able to do so. Instead, it considered it better to let the industry develop, this promising fishery without restriction. This was in accordance with the main objective of its fishery policy, to produce more protein food from the sea in order to close the protein gap in the diet of the Thai people.

In 1965, analysing the status of trawl fisheries on the basis of research results obtained through 1964, Tiews (45) warned again that "one should be aware, as has been expected, that some fish species obviously cannot stand a larger trawl fishery". It was pointed out then that already, in view of a considerable reserve of fishing power in the existing fleet, no new fishing boats should be built.

In 1967 Tiews, Sucondhamarn and Isarankura (49) again reviewed the trawl fishery situation. They came to the conclusion that in 1966 the trawl fishery was exploiting the bottom-fish resources heavily, and that although fishing did still pay it was high time to introduce effort regulations. The authors stated that of the various kinds of regulations used in world fisheries, a regulation of the mesh size would not solve the problem because many fishermen depended mainly on catches used for industrial purposes. These fish are normally of small size only, as is much of the fish used for human consumption also. An increase in mesh size would result in a complete loss of these catches. It was urged that regulation of effort should include a change in the distribution of effort on the fishing areas, and that no new boats should be licensed for trawl fishing in the Gulf of Thailand, or at least in certain parts of it. In order to diminish the fleet stationed in the Gulf, which was already too large for this area, it was proposed to shift part of the fleet to the Andaman Sea side or to fishing grounds outside the Gulf of Thailand. It was also suggested that the example of certain European countries might be followed, which pay premiums to retiring fishermen if they will break up their boats and thus guarantee that they will not remain in the fishery.

As can be seen from Tables 2 and 3, the drastic decline of catches per unit of effort in the experimental trawl fishery of R/V PRAMONG 2 continued in subsequent years and reached a new low in 1971, this being the last year for which data are available to the author (11, 25, 26, 38, 39).

During recent years discussions on how to regulate the fisheries have been continued. Other regulation measures, such as closed seasons during spawning time, a quota system, or closed areas for the protection of spawning stocks, were found not to be applicable: many

of the numerous species caught spawn practically throughout the year, the statistical service is too poor to control quotas, and for most demersal fishes it is impossible to define the spawning areas to be closed. The situation is different in the case of the important mackerel fishery: here, the introduction of closed seasons was found to be useful and has been applied successfully for some years.

As a result of these discussions, the regulation of effort through the restriction of the number and the size of fishing boats is being considered the sole practicable means for the regulation of Thai trawl fisheries. However, until now the Government has not taken any action, not least because of the sensitive political impact of such a policy. The ship-building industry does not wish to stop building ships, which would mean new unemployment; the trawlers do not want to be shifted to other harbours because this would mean changing their domicile; and certainly nobody is interested in stopping fishing and losing his job.

The only measure implemented so far is to grant loans to those fishing boat operators who are willing to acquire larger boats for distant-water fishing outside the overexploited coastal areas. But there are doubts whether such a measure can really bring the desired relief to the overexploited resources. One must fear rather that these boats will one day create additional fishing pressure on the local fishing grounds, when distant fishing grounds also become fully exploited, particularly by the countries bordering them who can certainly fish more cheaply with small boats than these larger boats can, so that expensive large boats would be unable to compete on such grounds.

## 7 PROBLEMS FOR DEVELOPING ADEQUATE MANAGEMENT POLICIES IN TRAWL FISHERIES

There are several problems in developing adequate management policies in Thai trawl fisheries. Attention is drawn especially to the five points below:

(a) The greatest handicap in the formulation of management policies is the lack of sufficient catch and effort statistics. The monitoring of catches is a matter of fact extremely difficult, as the Southeast Asian trawl fisheries are multi-species fisheries, with larger numbers of species than in practically all other fisheries of this type. These species are so hard to distinguish that even taxonomists have difficulties. Another problem is that the catches are landed along the coast so that a large staff of trained personnel, which so far is not available, would be needed for proper handling of the matter. In this connexion, the activity of FAO Fisheries Department in clarifying the identification of the more important fish species in the region is highly appreciated. Such activities deserve highest priority.

(b) The trawl fishery utilizes 200-300 different fish stocks, for which adequate biological knowledge has still to be acquired. In several cases even the taxonomy is not fully understood. Because of this species diversity, this is a much larger job than that faced by countries in the temperate zone which exploit only a few species of fish.

(c) According to Gulland (17) the biological factors which are important to management decisions can be described by the relation of the catch to two elements: the intensity of fishing (more precisely the fishing mortality coefficient, or the proportion of the stock which is caught per unit of fishing time), and the sizes of fish caught. While it is easy to determine the sizes of fish caught, calculating the intensity of fishing is extremely difficult for two reasons. For most of these tropical trawl fishes, direct age determination is impossible, as there are no special annular marks on vertebrae, scales or bones that are related to age because of their continuous and equal growth throughout the year in the tropical climate. The other reason is that, as many experiments in Thailand have shown, no suitable tagging methods are available for nearly all of the trawl species and it seems doubtful whether many of them will be successfully tagged in future (9), although there has been some success with dart tags on Priacanthus and Soolopsis. It is also impossible to establish abundance indices by echo-surveys as the trawl fish give hardly any traces on echo-recorders.

Since tagging experiments cannot be used for nearly all the demersal fish species, no direct information on the amount of intermingling between neighbouring areas is available. But there are indications from the species composition of catches that many of the species do not migrate far. For example, it is obvious that the species composition of trawl catches changes from north to south and also from Thai waters to Malaysian waters. Even if it is likely that, in the case of some species, depleted resources may be recruited from neighbouring less-depleted areas; other species may be so sedentary that the introduction of a closed season in one area would have very little effect on others. This is also indicated by the relatively large differences in the catch per unit of effort between different subareas which result from differences in fishing pressure; these are not smoothed out to the degree that would be expected if there were extensive movements of fish from area to area. On the other hand, if this observation holds true generally, it means that an overexploitation of demersal fish stocks on the Thai coast does not greatly affect the demersal fish populations along the coasts of neighbouring countries. From this it would follow that the management of demersal fish resources in Southeast Asian countries is more a national than an international affair, except in areas where trawler fleets of different countries intermingle.

(d) Under the conditions of the Thai trawl fishery the only exact information reflecting the status of the resource and of the fishery are the research data collected by R/V PRAMONG 2. These data demonstrate that in most of the subareas the catches per unit of effort have fallen to a level which no longer permits an economically sound fishery in the Gulf of Thailand. In the light of the research data the Thai trawl-fish catches appear to be overestimated, as the following considerations demonstrate. Although the author is not able to judge how accurate the fleet statistics of the Thai Department of Fisheries are, it is likely that, since they are easier to obtain, they are more reliable than the catch statistics. If one calculates the catches on the basis of the trawler-fleet statistics and on the average catch per unit of a standard trawl made in the Gulf of Thailand off the coast of Thailand (mean of Subareas I-IX, Table 2), it is evident that the 1970 catch cannot have been larger than some 766 000 metric tons (Table 7), instead of the more than 945 000 metric tons indicated in the Thai fisheries statistics (Table 5, rows 2 and 3). It is likely that even the 766 000-ton estimate is too high, since it was made assuming that the 67 fishing boats over 25 m and the 644 fishing boats of 18-24 m went fishing in new fishing waters outside of Subareas I-IX off the Thai coast (Fig. 2, Table 6).

The figure of 766 000 tons has been estimated by assuming that the 711 biggest trawlers fished day and night, as is the present practice, and yielded annually 750 metric tons; while the smaller boats remained in the Gulf of Thailand fishing the heavily exploited stocks, which in 1970 were reduced in density by some 60 percent as compared with the original level for the unfished stocks in 1963 (Table 2). It was also assumed that boats of 14-18 m have not more than half of the fishing power, and boats below 14 m not more than quarter of the fishing power, of the boats longer than 18 metres.

However, these assumptions probably cannot stand a critical review since many of the larger boats, if not the majority, continued fishing in the overexploited areas at reduced fish stock densities. So in a second attempt to estimate the trawl catches I have used the more likely assumption that 400 of the 644 18-24 m boats were mainly fishing in Subareas I-IX (Table 7). Under this assumption the total catch of this fleet was even less than 600 000 tons (589 000 tons). This estimate is a little higher than that made by a fishery census conducted by the Fisheries Statistics Section of the Thai Department of Fisheries, which came to the conclusion that in 1968 a total catch of 509 000 metric tons (609 million Baht) was obtained (15). As Tables 6 and 2 indicate, fleet size and catch per unit of effort were rather similar in the two years 1968 and 1970. The Thai authors believe, however, that a reduction of 20 percent in this estimate might be required in order to make allowance for bad weather, engine troubles, etc.

The catch calculated for the trawlable grounds off the Thai coasts facing the Gulf of Thailand and the Andaman Sea were some 356 000 tons (Table 7) and thus are close to Tiews' (45) estimate of the potential yield for these waters (390 000 tons). This means that there

Table 7. Two estimates of the catch of Thai trawl fisheries in 1970

| Size of boat | Number | Catch per boat in metric tons | Fishing locality | Total catch in metric tons |
|---|---|---|---|---|
| above 25 m | 67 | 750 | Juvenile fishing grounds | 50 000 |
| 18-24 m | 644 | 750 | Juvenile fishing grounds | 480 000 |
| 14-18 m | 1 172 | 40% of 375 | Sub-areas I-IX | 176 000 |
| below 14 m | 801 | 40% of 187 | Sub-areas I-IX | 60 000 |
| | | | | 766 000 |
| above 25 m | 67 | 750 | Juvenile fishing grounds | 50 000 |
| 18-24 m | 244 | 750 | Juvenile fishing grounds | 183 000 |
| 18-24 m | 400 | 40% of 750 | Sub-areas I-IX | 120 000 |
| 14-18 m | 1 172 | 40% of 375 | Sub-areas I-IX | 176 000 |
| below 14 m | 801 | 40% of 187 | Sub-areas I-IX | 60 000 |
| | | | | 589 000 |

is no further possibility of expanding trawl fishing in these waters. The further decline of 32 percent in the catch per unit of effort observed by R/V PRAMONG 2 in 1971 (Table 2) signalizes a rather severe overexploitation of the resource. Despite the great difficulties which exist for developing scientifically-sound management policies, it is already obvious that a drastic reduction of fishing effort is urgently necessary. There should be not only a complete cessation of trawler construction, but a reduction in the number of trawlers by at least one third should be aimed at.

In order to develop better management policies systematic internationally-coordinated aerial surveys along the entire coast of the Gulf of Thailand, the Andaman Sea and adjacent seas were recommended to the Thai, Malaysian and Indonesian Governments during the last visit of the author in the region in early 1972. This would make possible a more accurate assessment of the size of the fishing fleet and its distribution on the trawlable grounds.

(e) Another problem is that, although alarming signs of overexploitation of demersal fish stocks have been evident for some years, the political situation in Thailand did not permit the implementation of regulatory measures. Thailand is certainly no exception in this respect; rather, such difficulties exist to a varying degree in many of the developing countries in Southeast Asia and in other parts in the world. In comparison with the difficulties encountered with the implementation and the enforcement of fishery regulations, fishery development in countries such as Thailand seems to be the easier task. One fears that Thailand will not be the last example of the overexploitation of demersal fish resources. Many of the developing countries have just reached the stage, financially and technically, of initiating large-scale marine fisheries. On the other hand, nobody can blame the countries concerned if they follow the philosophy that it is better to begin large-scale sea fisheries, even without being prepared to take adequate measures for controlled development and so risk overexploitation, than it is to leave them unexploited.

A process of learning, however, is taking place in Southeast Asia. Malaysia may have succeeded in avoiding the difficulties experienced in Thailand by having restrictions on

trawl fishery development enforced from the beginning. As a consequence its trawl fishery is still economically sound. Looking to another neighbouring country, it is also unlikely that the mistakes of the Thai trawl fishery development will be repeated in Indonesia, and this for three reasons: firstly, there is much less capital available to be attracted to fisheries; secondly, their fisheries are much less developed than they were in Thailand when trawl fishing was introduced; and thirdly, the present political system permits a better control of fisheries development.

## 8 CONCLUSIONS

The example of the Thai trawl fisheries development permits several conclusions and observations of some generality:

(a) The most striking observation is perhaps that the Thai fishery has developed tremendously almost up to its maximum potential, without any sophisticated training programmes. Although the situation in Thailand prior to the phase of rapid development might have been a very special one, at least some of the training programmes to which so much attention is being paid in many of the developing countries may be unnecessary. In many cases costly training centres, fishery schools or even university colleges produce experts in excess of any real need. Critical reviews of such training programmes are therefore urgently necessary.

(b) It requires well balanced activities to initiate development. There is no general code of practice, but doing the right thing at the right time has not always been achieved in fisheries development programmes. The Thai trawl fisheries development is a good example of a straightforward programme. Summarizing, the very first activities were directed toward developing a suitable trawlnet. Immediately thereafter an exploratory fishing programme, to assess the trawl fishery resource was carried out, together with a "training by demonstration" programme. Since from the very beginning a standard fishing gear was adopted under German bilateral aid activities, repeated surveys of the resource under a research programme have made it possible to recognize changes in the resource which occurred as the commercial fishery developed. Such research activities are indispensable also in the future, since they provide the only reliable data concerning the status of the resource, and they are needed also to control the significance of fishery statistics, etc.

(c) The Thai example has taught that one of the major activities of a fisheries administration must be to build up an adequate statistical service, without which sound management is impossible. Fisheries administrations pay far too little attention to this most important activity. This is true not only in Thailand but also in many other developing countries. It is felt that the Fisheries Department of FAO should considerably increase its advisory activities in this field. More training programmes on all aspects of statistical data collection are needed, including training on species identification. Above all, proper species identification sheets need to be prepared. If fisheries statistics are not improved, all the activities of the FAO Fisheries Department, UNDP, fishery councils and bilateral aid agencies directed toward development and management of fisheries will be more and more hampered. Exact statistics are the prime prerequisite for knowing where exactly we really stand.

(d) While Thailand has available a continuous record on the changes in the size of catches from its research activities in the Gulf of Thailand, for future consideration it is also necessary to collect exact catch and effort data from boats that fish outside of areas I-IX of the Gulf of Thailand, according to the geographical areas being fished. To start with, log-books should be distributed and filling them out should be made compulsory.

(e) Since Thailand is exploiting its marine fisheries resources almost fully and in many instances is already overexploiting them, in future the main research emphasis must be on the development of aquaculture. This is the sole major means of further increasing fish production. In this connexion mussel and oyster farming deserve special attention, as one can expect huge potentials for these types of mariculture in Thai coastal waters. In

addition, fish and shrimp culture may assume larger importance if appropriate techniques are developed; eel farming is another possibility. Some research activity is in progress, and should be greatly increased.

(f) The bilateral aid activity of the Federal Republic of Germany in Thailand in the field of fisheries has been found extremely satisfactory by both Governments. This effective and relatively inexpensive project has shown once more that it is essential to carry out such projects over fairly long periods. It is now more than 14 years since the author first gave advice, and 12 years since the project became operational. In the latest partnership arrangement between the Marine Fisheries Laboratory of the Department of Fisheries in Bangkok and the Bundesforschungsanstalt für Fischerei in Hamburg short-term assignments of German experts in Thailand are possible, in order to make more use of experts who would not be available for longer assignments. This arrangement sets an example for a new type of bilateral aid, especially suited to overcommitted research institutes that cannot dispense with scientific staff for long periods.

The Bundesforschungsanstalt für Fischerei has found, however, that its staff (60 scientists, 140 technicians) would hardly be large enough to establish similar partnership arrangements with developing countries in other regions. In view of these limited capabilities, which are normal also for other similar institutes, concentration on the problems of one region only is necessary in order to obtain the experience required to provide really expert advice. The effectiveness of this project makes it desirable that other well known research institutes in the countries rendering technical aid follow the example of the Bundesforschungsanstalt für Fischerei and take over similar responsibilities and partnership arrangements with developing countries in other regions.

If such sisterhood relationships could be systematically established over the whole world, one could expect a new surge of fisheries development, management and research in the developing countries. Such countries face problems that in many cases are more complex than those faced by the donor countries, as this paper demonstrates.

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# A SYSTEMS VIEW OF FISHERY MANAGEMENT WITH SOME NOTES ON THE TUNA FISHERIES

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## 1 INTRODUCTION

Contemporaneous technological development is at high level and continues to accelerate and yet, unfortunately, at the same time, many of the serious problems of the world have not been ameliorated by this development - indeed, in some instances the problems have become more severe. It is a seeming paradox, that we have, in fact, in principle, the technological capability of solving many of these problems and yet in many instances solutions have not been forthcoming (cf. Churchman, 1968). The reasons for this paradox lie in the fact that our problems are no longer as simple as they once were and techniques carried over from more halcyon days when problems could be solved on a piecemeal basis, in a more or less leisurely fashion, are no longer adequate for reaching efficient solutions to our present day problems, which have reached such complexity that we might call them superproblems. Fortunately, however, techniques have been developed and are being developed to handle these superproblems. These techniques are oriented toward asking the "right questions" and are collectively called systems analysis.

Fisheries management, just as the other problems to which we have alluded, has also increased in complexity from the days when students considered the resources of the sea to be inexhaustible; when fishery management essentially involved examining the dynamics of relatively few species in vacuo; when interesting biological questions took precedence over questions of the dynamics of the stocks; or when the limited mobility and moderate fishing power of fishing vessels virtually obviated the need for considering international aspects of fishery management. By contrast, we have today a situation in fisheries where individual fishing operations can exert tremendous intensities of fishing effort and deplete a stock in a matter of weeks or months; where the number of overexploited stocks continues to grow; where some stocks continue to become virtually extinct; and where the community of individuals who harvest and process the stocks are, in many instances, neither held accountable nor do they demonstrate a responsibility to conserve the stocks by not overfishing, by not insisting on and supporting research of relevance to fishery problems; and by not contributing needed management data or contributing data that either contain an inordinate amount of errors or are not timely. These complexities require that the contemporaneous manager face the above questions and answer even more complex questions concerning how resources should be allocated in the time stream, how resources should be allocated among the states, and how criteria should be established to evaluate the resources so that appropriate allocations can be accomplished.

These complexities afforded by fisheries have been recognized, in varying degrees, over the last two decades. For example, Chapman (1966), reflected upon the involvement of fisheries with institutional problems and Holt (1969) observed, perhaps wistfully, that

> "... Many of us were optimistic when 20 years ago we began proposing quite reasonable net-mesh regulations to conserve the young of certain fish stocks. Then we saw these simple - I suppose oversimple - ideas bog down in consideration of precisely how to measure a particular kind of twine, and how to take account of the innumerable special situations that countries pleaded for, so that fishery research seemed to be becoming perverted from its earlier clarity and broad perspective."

Even though there has been growing recognition that fisheries management is a complex of many problems, it appears that we have not adequately recognized the need to develop techniques to handle these problems.

The traditional pursuit of problem-solving in fisheries generally involved attempts to satisfy the scientific curiosity of a small subset of the very broad community of individuals associated with resource problems. The questions that were asked and the problems that were chosen for solution were philosophically oriented toward the scientific approach. Thus, the view of a problem was borne forth on a spark of intuition; hypotheses were formulated and tested, and the hypothesis which was better than the alternatives was submitted to the scientific community, to await inevitable successor hypotheses. The modus operandi in the scientific approach is to search for knowledge and the solution of problems or the generation of advice was not a primary output of the investigation and furthermore inquiries into the interfacial areas between natural phenomena and the more mundane circumstances of everyday human affairs tended to be discouraged. It is, of course, not our purpose to cast what certainly must be petty aspersions on the scientific method, but rather to point out that adherence to the scientific method may have led to asking the wrong questions about the real-world problems of resource management.

1/ This quotation is of interest from two points of view. First, it described the complexities. Second, it reflects a view which might be antithetical to the systems approach because it reflects a concentration upon the mesh problem itself - a problem which could not be solved without taking a broader, perhaps a systems, view of the special cases of the countries involved.

An important alternative to the scientific method is systems analysis, which I believe contains the scientific method as a subset. In this context systems analysis becomes a mechanism which guides which "science" should be attacked by the scientific method. The distinction between the scientific method and systems analysis has been of fundamental importance to the development of systems analysis. Table 1 follows Quade (1964) in contrasting systems analysis and the scientific method. It is of interest that Gulland (in press) recently drew attention to the scientific method approach in fisheries.

Since systems analysis is a technique for investigating complex problems, and we acknowledge the complexity of the fishery management problem, it seems quite appropriate to apply this sort of analysis to fishery management. It is most difficult in a paper as short as this to detail a systems analysis of fisheries in general, or even to detail an analysis for a group of fisheries such as the tuna fisheries. Instead of detailing an analysis, we will try and provide an exposition on the approach to such an analysis, and in so doing, we will be primarily concerned with some necessary prolegomena and an elucidation of some of the structures and techniques that might be involved in an analysis. Our general theme will be that we are taking too narrow a view of fishery management.

TABLE 1

Contrast Between Orientation of Systems Analysis and the Scientific Method

| s Analysis | Scientific Method |
|---|---|
| . Suggests policies | . Seeks contribution to knowledge |
| . Offers advice | . Seeks understanding |
| . Philosophy in action | . Seeks predictive ability |
| . Considers immediate, diverse, and complex questions of practical value | |

## 2 SYSTEMS ANALYSIS

To begin I should like to describe some of the rudiments of the systems approach and then use these rudiments to gain a systems view of fishery management.

The systems approach arose as an outgrowth of the "operational analysis" that was so useful in solving operational problems during the second world war. The central theme in systems analysis involves using the analysis to ask the right question by cycling iteratively through (1) defining objectives, (2) designing alternative systems to achieve these objectives, (3) evaluating the alternatives in terms of costs and effectiveness, (4) questioning the objectives and other assumptions underlying the analysis, (5) using this examination to open new alternatives, and (6) establishing new objectives. Once the new objectives are established, the cycle is re-entered at step (1) and continued until a satisfactory interpretation of the problem solution is needed.

If we were to pursue the first task, the problem of defining objectives, in more detail, we should see that this would involve examining in some detail the formulation of the problem in terms of its context, the assumptions involved, and the criteria that would be used to judge various alternatives. Thus we can see that there is a heavy emphasis on the fomulation and definition of the problem - then, through successive iterations, the problem objectives and definitions are continually evaluated and appraised and, perhaps, even reformulated. As the problem is manipulated, various alternative solutions are generated and the worth of any of these is adjudged by the analyst in terms of systems criteria and goals established in the formulation of the problem.

The generation of systems criteria and goals are fundamental to the prosecution of systems analysis and the concepts of suboptimization and proximal criteria are in turn fundamental to establishing the goals and criteria.

The concept of suboptimization reflects from the fact that systems problems are a plexus of sub-problems. Because of this it is not possible to easily grasp and optimize the big or superproblem. Rather, it is necessary to break the big problem into subproblems, each of which we can define

precisely and adequately conceptualise. The danger in this is that optimality in the subproblems may not be consonant with optimality of the entire system and this is the danger of suboptimization. Thus the analyst must suboptimise to grasp a problem, but the suboptimisation should be consonant with the goals of the entire system; if it is not, then further iteration analysis cycle is required.

The other concept is that of proximate criteria. We frequently state our goals in terms of rather sweeping generalities. We want to optimise the yield of fish. We want maximum sustained yield. We want fishermen to have a "good" living, etc. A little reflection will show that each of these goals can be interpreted in such a variety of ways that their use in guiding the direction of a system is limited. Because of the operational vagueness of "optimising yield", "maximum sustained yield", and "good living" the systems analysts construct what are called proximal criteria, which, in contrast to the vague terms, can be used to actually adjudge the performance of the system.

Thus systems analysis involves an iterative examination of a problem being careful not to sub-optimise and concentrate upon too narrow segments of the problem using criteria which might not be consonant with higher level goals of the system. A systems view of a problem involves examining a problem in terms of its context, formulation and assumptions preparatory to analysis.

How does our present view of fishery management fit in with a systems view of fishery management? First of all our present view of fishery management tends to be essentially biological. Although there is an increasing awareness of the economical, biological, legal, etc., aspects of the resource problems, 2/ attention still tends to be focused on finding, for example, that level of effort at which catch is maximised or that level of fishing effort and recruitment size which maximises yield per recruit. Despite lip service paid to the economic aspects of management, economic considerations seem to have had little influence upon the actual management of fisheries and we must of course face up to the possibility that the economic models are not able to cope with the externalities, the common property nature of the resource, and the stock-producer-processor interaction which seems to assure the processor with a steady flow of raw material at the expense of moving from stock to stock, overfishing each stock seriatim, and thus obtaining a much lower yield than would be obtained by proper management of each stock.

Thus, we can see if we view the fisheries resources of the world as either a source of protein or simply as a raw material transformable into goods and services for peoples of parts of the world where the fishery resource is the important raw material, that perhaps our present yield criteria are sub-optimal (a situation which is generally recognised, but not acknowledged), and in view of the ineffectuality in terms of man's use of fish resources, many existing regulations and approaches to management are in need of more proximal criteria to provide guidance and strategies in stock exploitation. So as we begin to take a systems view of fishery management we see that perhaps we have not formulated management in broad enough terms. Let us consider management from a broader point of view.

## 3 THE ROLE OF MANAGEMENT

There is tremendous literature on the roles and objectives of management, and it is quite impossible to recapitulate all of this. Rather, I would like to paraphrase some remarks by Drucker (1969), who, in a recent paper, drew some clear distinctions between the "old assumptions" of the role of management and the "new realities" of the role of management. Although these views are intended to reflect upon the management of the firm, it is clear that they are also applicable, in a variety of contexts, to the management of fishery resources.

Drucker begins by observing that "... all institutions will have to make fulfillment of basic values, beliefs, and proposes a major objective of their continuing activities rather than (having) a social responsibility that restrains or lies outside their primary functions. Further, the quality of life is, in fact, a business opportunity and can be converted into profitable business. There should be more emphasis on adapting the institutions to the needs, aspirations, and potentials of the individual than on adapting the individual to the demands of the institution." Entrepreneurial innovation was not formerly intrinsic to management, but now such "... innovation will become the very heart and core of management ... Existing institutions will have to reach out for change as an opportunity, (and) will have to learn to resist continuity." Management should also make knowledge more productive, and Drucker points out, here, that in the production of knowledge, there is no single best way to doing a job and "... there can be no divorce of planning from doing in knowledge work."

Drucker further points out that management should "... be considered as both a science and a humanity." In this respect "... management is ... a culture and a system of values and beliefs and serves as a channel through which society can productively utilise its values and beliefs" and final emphasis is placed on noting that "economic and social development are the result of management."

2/ For recent detailed consideration of nonbiological problems see e.g. the proceedings of the recent FAO International conference on investment in fisheries, or Scott, 1970

Thus, for example, "... there are not underdeveloped countries. There are only undermanaged ones."

At first glance, the new realities of management may seem far removed from fishery The new realities are, in fact, far removed from fishery management. The distance between the realities and fishery management does not arise from any intrinsic property of either the new realities or of fishery management per se. The distance does arise, however, from the attitudes of the institutions involved in resource management and this is why fishery managers have traditionally viewed management from a maximum-sustained-yield point of view which optimises the yield from a single resource, but essentially leaves the international problems, the political problems, the economic problems, the legal problems, the utilisation problems, etc., to the vagaries of chance.3/ Insofar as these other problems lie at the heart of fisheries, it seems, especially if we take the systems view of fisheries, that we should begin to describe our fishery system in terms of all of these problems and the criteria for the way we approach the total problem could, quite appropriately, be set forth in the new realities for

Thus, the new realities suggest, with respect to fishery resource management, that the institutions involved in managing, harvesting and processing the resource are accountable for improper allocation of the resource. The best allocation is that which makes the greatest contribution to the quality of life of the individuals that own, 4/ harvest and process the resource.

In order to formulate the mechanisms of accountability we need to consider management from the point of view of the needs of the peoples that are associated with the resource and not from the perhaps crystallised modus vivendi of the existing institutions. The institutions need to become much more dynamic and fluid so that they be responsive to the changing needs. Further, we must consider the resource management to be not only the responsibility of the institutions which traditionally manage the resource but the responsibility of the fishermen and processors as well. All of these people are responsible for progress and innovation. Basically, we need to develop a system of values for our resources.

Thus the role of fishery management basically says very little about the way in which resources should be harvested. Rather it concentrates on developing satisfactory linkages between the people that use the resource and the resource. In order to develop these satisfactory linkages, it is necessary to define the goals of

## 4 THE GOALS OF FISHERY MANAGEMENT

In thinking about goals in general, we generally think of attainment of well-being in some sense, and insofar as one important aspect of well-being is economic, we quite naturally think of economic goals. A suitable set of economic goals might be to attain economic efficiency. Economic efficiency might be interpreted with various shades of meaning. For example, Dorfman (1967) views economic efficiency to include efficiency in distribution, efficiency in production, and consumer sovereignty. Using these criteria, an efficient economy will distribute its resources or production of the resources to the people that need them will fully utilise its resources and place high consideration on the needs of the consumer.

A beginning toward economic goals was stated in the Panel Report of the Commission on Marine Science Engineering and Resources. The idea is that we should judge the production of commodities from fish just as we judge the performance of other industries. In this regard the Panel noted these objectives to be (1) that the marginal cost of production should just equal the marginal value of the project, (2) that the catch be taken at the lowest possible cost, (3) that management should contribute to the invention of new fishing methods and their innovation and finally, (4) that the income from a fishery should be shared by the participants in a fishery and should be no worse than incomes earned in other activities.

Now there are a variety of criteria that might be of use and one which is used in business management is the return on investment criterion. In other words, an entrepreneur has a certain amount of capital which he wishes to invest. How should he invest his capital to maximise the return on his investment?

3/ I fully realise that fishery management is being pursued from a broad point of view considering economic, legal, marketing, etc., aspects of the fisheries. I raise the question, however, whether the views from these various disciplines have been sufficiently integrated and note again, in this respect, that much of the actual practice of fishery management involves the single yield maximisation concept.

4/ But most of our fishery resources are not "owned". I am taking the liberty of looking at the futures which indicate the inevitability of ownership sensu latu.

Which investment project, among the available alternatives, should he choose? When should he make his initial investment and how should his investment be distributed in the time stream? These are essentially problems in capital budgeting.

## 5 MORE PROXIMAL CRITERIA

While the economic goals set forth are undoubtedly the goals that our fishing system should follow, they are, in a sense, overdetermined. That is, saying that we should be more efficient or that we wish to achieve a better distribution of income neither provides the guidance, nor the information on how to achieve these optima. From the point of view of the fishermen and the processor and others that might benefit from the resource, it is evident that a more immediate criteria is that of obtaining reasonable wages and a reasonable return on investment, but even here, as we have pointed our previously, we should specify what we mean by "reasonable", so that our criteria can become operationally useful. We can see that the economic criteria have the potential of being consonant with the roles and objectives of management and it remains for us to determine how they can be applied to fishery problems.

There is a considerable amount of literature on this subject and concise review of the subject may be found in Baumol (1965). Baumol, for example, gives the following capital budgeting model which I have modified slightly to make it conformable with fishery problems:

Suppose we contemplate $i = 1, \ldots, k$ investment projects. The $i^{th}$ investment project could refer to a fishery or to a fishing ground we wish to harvest and our level of investment in the $i^{th}$ project would be denoted by $X_i$, the number of vessels (say) that we wish to the $i^{th}$ project. Let $N_i$ be the net discounted present value of the expected future returns on a vessel committed to the $i^{th}$ project. $m_{it}$ is the amount of money required to support the $i^{th}$ project during the $t^{th}$ time interval and the total amount of money available for investment in period t is $M_t$.

It is a relatively simple problem then to choose that level of activities for each project ($X_1, \ldots X_k$) in such a way, so that $\Sigma N_i X_i$ is maximized, subject to $\Sigma m_{it} X_i \leq M_t$ for $t = 0, \ldots, T$ and $X_i \geq 0$ for all i. What is not simple is the variety of assumptions that are attached to utilising the above model and I will not take space to go into these since they all discussed in the literature. Our main point in presenting the capital budgeting approach is to give an example of a criterion, namely, maximization of the present value of various fishery investment projects. There are, of course, other criteria that can be formulated.

The capital budgeting example is useful for another purpose in that it makes use of the concept of changing values in the time stream. The discounted value is a fundamental property of value-involved criteria and is therefore worth brief discussion. In order to compute the discounted present value of an investment scheme we must consider the cost stream ($m_0, m_1, \ldots, m_t, \ldots, m_T$) and the benefit stream ($b_0, b_1, \ldots, b_t, \ldots, b_T$). The discounted present value of an investment scheme is, as is well known,

$$N(I) = \sum \frac{b_j - m_j}{(1+I)^j} \qquad (1)$$

where I is the interest rate which is taken to be fixed and known and undertaking any project with a positive present value will increase the firm's future amount of money.

It would then be quite useful to determine the present value of various fisheries. It would, for example, be useful for the investor because he would want to invest in fisheries with the highest present value and also for the research administrator because he too has finite funds and must guide his research to the most profitable activities which might be adjudged in terms of incremental present value generated by a research scheme.

It might seem quite difficult to compute the present value of various fisheries. Nevertheless, it might be a useful exercise. The first step would be to decide on T, the time horizon. The value of T should be set such that circumstances occurring for $t > T$ are so uncertain that the benefits accrued from including them in the analysis is less than the costs which would be generated by including the events which occur at $t > T$ in the analysis.

The next problem is how to determine the appropriate interest rate. There is no advice for a specific interest rate. The chosen rate should approximate that currently in use in the business community and should perhaps be increased several percent to account for the high risk factors that normally affect fishing operations.

Now given a time horizon and an interest rate, the items that are really interesting are the benefits and costs. Traditionally, we tend to view the benefits and costs from a fishery operation as constants rather than variables. Thus, instead of thinking of costs in terms of deploying a fixed number of vessels and benefits in terms of the per annum tonnage of the catch, it might be useful to think in terms, given our knowledge, of population dynamics, etc.; certain strategies might affect the $c_j$'s and $m_j$'s and consequently the particular F (I) and how this in terms might affect the levels of $X_i$ in our allocation scheme.

Naturally one does not expect to obtain precise values in the above approach, but even approximate values will indicate the sensitivity of the particular problem to parametric changes in the $b_j$'s, the $m_j$'s, I and T, and perhaps offer us some new insights to the data required for management and our management procedures. For example the maximum sustained yield criterion which is in vogue as the management criterion but has been correctly criticised by Gulland (1968, 1969) presents some difficulties when viewed in the context of equation (1). It is quite conceivable under the discounted present-value criteria that we should want to engage in a programme of overfishing in some years and underfishing in other years. The operation of this approach could be governed by maximising the catch as suggested by Riffenburg (1970).

Thus the capital budgeting concept is applicable to the management of fisheries, and can be consonant with higher level economic goals and can provide more direct guidance to the decision-maker than the economic theory. We wish to emphasise, again, the considerable literature on this subject and that there are other budgetary criteria such as that related to the payback period and the internal rate of return, etc. Many authors feel that of all the budgetary criteria, the discounted present value approach is the most reasonable.

It is also of interest to observe at this point that the conservation of our resources is essentially an allocative process and the calculus that is conventionally used in fisheries is not a powerful technique for allocation. Consequently, our management of fishery resources has been governed by models which have been phrased in the language of differential equations and not in terms of mathematical programming. It would have been interesting to examine the status of fishery management today if the earlier models were allocative - there might not, for example, be a mixed species problem.

## 6 AN ALTERNATIVE VIEW

We have thus considered a systems view of fisheries management and we can see that it involves defining management in terms of rather broad concepts that would tend to clearly and explicitly interrelate and unify the concept of a fishery as a single complex of social problems, stocks, fleets, processors markets, etc. But this is essentially a spatially integrative point of view. That is, by our discussion, we have attempted to interrelate elements of the status quo and if we are to truly take a systems view then we must take a broad view temporally as well as spatially of fishery management. This can be attained by use of the subject of technological forecasting.

As indicated in the introduction our technology in general, has undergone tremendous contemporaneous development and in order to minimise the time lag with which our management institutions become responsive to these technological changes it would be wise to forecast technological developments so that the institutions can be responsive to the opportunities provided by the technological developments. In a recent article Bright (1970) noted that "assaying the future" might involve monitoring the technological environment for signals of technological change. These signals arise from events that are closely associated with innovation. Bright summarises these as follows:

> "... A radical new technological advance is made visible to society first in written words, then in increasingly refined, enlarged and more effective material forms, long before it achieves widespread usage.
>
> The potential impact of the innovation is usually evident years before the new technology is in use on a scale great enough to affect existing societal conditions appreciably.
>
> Social, political, and now to an increasing degree, ecological changes may alter the speed and direction of the innovation's progress, as I indicated previously.
>
> Innovation may be abruptly influenced by decisions of key individuals who control supporting resources or determine policies that affect their application.

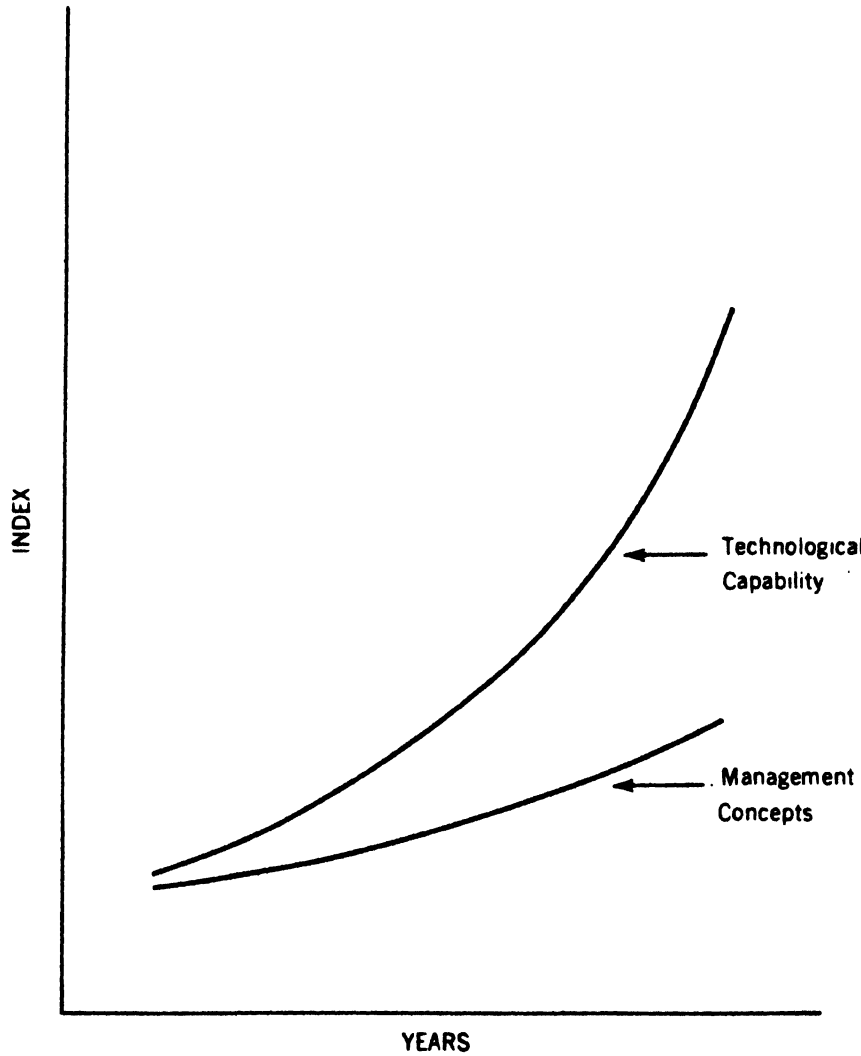



Figure 1. Relation between technological capability and management concepts adequate to fully utilize the technological development.

Technological capabilities - e.g., parameters such as speed, power, miniaturisation, strength, and capacity - increase exponentially over time, once bottlenecks are broken ... but it will begin to level off if they encounter scientific, economic, or social barriers..."

As we consider how technological change might affect fishing we should keep in mind another important concept and that is the general relation between management - the subject of this paper - and technological change. 5/

This relation is depicted in Figure 1, which shows that in general, technological capability is developing at a much faster rate than our management concepts. For a general example, our technological capability to transport people has far outstripped our ability to develop management concepts which transport people in an efficient manner. In other words, hardware has reached a much higher degree of sophistication than software in terms of development. For a more specific example consider that our technological ability to catch fish far excels our ability to manage the stocks.

Fisheries technology and management, just as in the general situation, present an evergrowing hardware-software gap, and we can forecast that this gap will, especially if we continue to take the narrow view of fishery management, grow fantastically large with the progress of time. This is because the hardware and technological capability that we ordinarily ascribe to fisheries in terms of boats, nets and gear are much too narrow. The field of fisheries has, in fact, access to the technological capabilities of undersea vehicles, tremendously sophisticated acoustic and other underwater communication devices, computer technology, etc. Yet the managers associated with the fisheries have not transformed these technological capabilities which are, in terms of fisheries, into innovations in the fishery field.

It would seem that forecasting of technology in fisheries must recognise that the most likely impact of technological advance will be the use of already developed hardware in fishery problems. It will not be possible to simply decree the use of this hardware, but rather it will be necessary to take a systems approach to the application of this hardware using highly trained specialists.

So not only will we have fisheries develop, primarily by increasing the hypothetical index of management concepts to meet technological capability, but also along certain lines for which there are ample technological signals. Using Bright's criteria in terms of the technological signals and optimism that fisheries managers can reduce the management - technology gap - largely by increasing management capability - I have forecast the technology of fisheries that looms just beyond the horizon, (Rothschild, in press).

"....as we view fisheries in the context of the '70's,... we have not been establishing the right criteria concerning the growth of our fisheries. If we do not have the right criteria, then we have no hope for asking the right questions. I think that we have been too concerned with describing the <u>status quo</u> rather than probing the future.

In thinking of the fisheries of the future, we need to think of

(1) Fleets that are highly mobile and are able to fish anywhere in the world. Such fleets already exist.

(2) Fleets that are modular in the sense that if purse seiners or certain refrigeration or processing capabilities are needed, these can be taken off the shelf and plugged into a particular expedition as required. The concept of modularity is a very useful device in constructing systems because a modular construction usually exhibits a lower cost structure, increased reliability, and greater ease of management than non-modular systems. A modular fleet will require a new attitude toward fisheries, re-design of equipment and a much larger management unit than presently exists for most U.S. fisheries.

(3) Fleets that exert tremendous amounts of fishing intensity. Such fleets are also already in use. The advantages of fleets that are capable of exerting tremendous fishing intensity are coupled with mobility and modularity so that a high intensity pulse of fishing effort can make most effective use of the fish stock and of capital equipment. In general, we should like to harvest the fish at the "instant" corresponding to the point when it reaches a peak

5/ This concept was brought to my attention by George Rounds of Temps Incorporated

biomass (we are assuming, to simplify our discussion, that harvesting at the peak biomass is economically optimal, an assertion, which is, of course, not necessarily true). Suppose we could harvest this optimal yield from a stock in two weeks; we have then picked the fish when they are "ripe" and our fleet is free and capable, by virtue of its mobility and modular construction of moving elsewhere and fishing.

(4) An entirely new approach to refrigeration or preservation or processing will be required. Because of the tremendous catching power of the fleets, it will be necessary to hold fish in a preserved state until they can be processed. This new technology would probably need to be quite radical since huge quantities of fish would need to be processed in a relatively short time.

(5) Development of concepts of ownership. The course of events in today's fisheries is such that the catch from a stock might be reduced 10-fold and decreases in effort would result in increases in yield. The "tragedy of the commons", however, prevails and there is little advantage to reducing effort, so the fishery moves to adjacent stocks and in so doing the catch today is 50 percent rather than 10 percent of its former magnitude. It appears that the principle of ownership of fish stocks will be required so that these stocks can be effectively utilised. It makes little sense to talk of effective utilisation without effective management and effective management is most hopeless without some concept of ownership. The development of ownership poses some rather enigmatic questions because its development places an obvious constraint on the mobility and other degrees of freedom that will be characteristic of the fleet of the future.

(6) The use of foreign sources of equipment and capital. This is already done in other industries. A modernisation of our equipment, in general, may not be sufficient to make fishing profitable. The cost-price squeeze requires examination of foreign labour for construction, repair, maintenance and even fishing.

(7) The development of a fishery information system. The fishery information system is computer based. It will store the time-space trends of fish abundance for all major stocks of fish in the world and similar trends for the minor but relevant stocks. At the end of each day's fishing, the catch, oceanographic, and meteorological data will be radioed to the computer. The computer will then advise the skipper his optimal strategy for the next day's fishing. The computer might even give the skipper a choice of strategies with the probability that each will pay off. Since the fleet is modular and mobile, the choices can be very wide. (The savings in the acquisition of ocean and weather data alone will be quite large.) At the same time, a processor can inquire of the computer system and find out the expected time of arrival of a load of fish because that information will be radioed to the computer by the skipper. The system will, since it "knows" the amount of fish landed and still aboard boats at sea, and also the landing trends for other years will be able to predict for the processor the nature of landings, days, weeks, and months in the future. The system will have an interesting device so that it will not give out information that would be competitively unfair until that information is competitively obsolete; an amount of time which might in some instances be measured in hours or days and in others months. Instead of managing a stock by setting a size limit or quota at the beginning of the year, management will be prosecuted with the aid of the system on a virtual real-time basis. In addition to all of these things, the computer will aid in capital budgeting, accounting, and day-to-day management systems of the firm or firms which utilise the system.

It is fairly obvious that the technological changes described above will not just happen. The effectuation of these changes requires stimulation from the community of individuals in the fishing industry. The problems that need to be attacked are too large to be undertaken privately; they need to be undertaken by government.

Such changes will basically result in aquaculture. Not the aquaculture that we traditionally think of, but an aquaculture of the sea where stocks are harvested as efficiently as in some of our more sophisticated agricultural techniques."

We can say that of the various technological signals that we have discussed, there is one that appears particularly strong and that is the computer. Computers are of course at a high degree of sophistication but are not in wide use in fisheries or in the development of the integrated management information system that we described earlier, to relay fishing strategies to the fleet, to provide information to the processor and to aid in more or less conventional management. We should not,

however, be surprised at the lack of computer aided management in fisheries because such a situation evidently existed in industry until only recently (Vandell, 1970). The reasons for this computer gap in industry have been manifold, according to Vandell, and understanding these constraints as they existed in industry may enable us to obviate the same constraints in fisheries. These involved the lack of trained manpower with well developed computer skills, a lack of understanding of the power of computer applications by executives and top decision makers; and a lack of software without which experimentation within an organization tended to be discouraged. These constraints are now apparently on the verge of being completely eroded in industry. We can consider that these constraints also apply to the problem of managing fisheries but they are nowhere near eroded away, and this is testified to by the rank confusion in which much of the world's simplest fishery data exist, let alone sophisticated management systems.

There is no question that if fisheries of the future are to conform to the above mentioned scenario that a computer oriented information system will need to be developed and fortunately there are concepts in the literature on information system development. In contrast to the more or less philosophical concepts on the role and goals of management, the concepts involving the information system tend to be, perforce, operational.

But just as we took the broad view of the philosophical approach, we should consider the operational aspect of management from a broad point of view. One such view is developed by Anthony (1965), who notes that:

(1) The starting point in construction of the over-all system should be management control, which deals with the ongoing operation of the whole enterprise.

(2) The management control system should be related to, but should not include, the processes for strategic planning, operational control, and financial accounting; the notion of a single all-purpose system is unrealistic.

(3) The central management control system should be a financial system since money is the only common denominator.

(4) Computers and mathematical models cannot be the essence of this control system.

At this point we can see, from Anthony's framework and his subsequent discussions, the evolution of some concepts applicable to the design of a fishery-management information system. The most important is that the activity of management is not monolithic, it should be considered in terms of high-level policy, strategic control; a tactical view, management control; and a day-to-day functioning, operational control. In relation to fisheries, we can then view the strategic control as the area in which fishery management institutions, fleet owners, resource owners, and processors set philosophy on regulation, species mixtures, etc. The management control is not fishery management per se but tactical control allocating, for example, vessels to catch fish in time-space coordinates and finally the operational control governs day-to-day vessel operations, etc. It is interesting to observe that if we view fishing as an integrated enterprise of fishing, processing, and fishery management, then we have a rather interesting paradox in the sense that from the traditional fishing management institution point of view, management focuses on the strategic aspects, yet most of the "action" in fishing is concentrated on the tactical and operational aspects, and, at any rate, there do not seem to be effective communications among the various levels. Thus, from these points of view fishery management is perhaps emphasizing the wrong aspects of any problem.

As an alternative to the existing management approach in fisheries we might indicate some ways of thinking about management from a strategic, tactical, and operational point of view. We will consider the strategic point of view in terms of existing management structures and then the tactical and operational problem. We will also consider the effect of considering the tactical and operational problems upon the strategic question.

The existing management structures involve consideration of essentially three conceptual approaches. These are the yield-per-recruit approach, the stock-production approach, and the stock-recruitment approach. These have been discussed in considerable detail in the literature and there is no need to replicate this discussion. There are, however, some points of detail that seem to be worth mentioning in connexion with tuna fisheries and possibly others as well.

First, the yield-per-recruit approach can now, with the aid of various tables (Beverton and Holt, 1966, Wilimovsky and Wicklund, 1963), be computed under a considerable variety of conditions. Various computer algorithms are available to not only compute the most often used Beverton and Holt yield isopleths, but Ricker's (1957) approach or any more or less arbitrary arrangement of growth and mortality over various intervals of the organism's life. In order to show the flexibility of this approach, we compare, using the Paulik and Bayliff (1967) computer algorithm and SYNAP plotting routine (see e.g. Rothschild et al.,1969), yield-per-recruit isopleths for a fish subjected to a 3 month and a 6 month fishery and the residuals between these two strategies. The appropriate life history details are outlined in Table 2. We can see from this particular example that the strategy of a 3 month season is always better than that of a 6 month season except at low selectivity size and high fishing effort. The point that we wish to demonstrate is that virtually any time-variable assumptions on mortality and growth can easily be incorporated in a yield-per-recruit model with the aid of tables and computer routines. In fact, in most instances, data will not be available to meet the full flexibility of the computational opportunities.

The second concept involves production models which are of fundamental importance in the management of fisheries. These models generally require only catch and effort statistics and do not explicitly require that the fish under study be aged. Tunas are notoriously difficult to age but catch and effort statistics are generally available and so production models have wide applicability to tuna problems. The main point to be made is that production models tend, owing to their relatively limited data requirements, to be simple. This simplicity tends to be superficial and misleading, however, because it is sometimes difficult to ascertain the extent to which the assumptions involved in the general production model are met. Because of their widespread use in tuna dynamics - I will briefly review the nature of these models and a few problems dealing with the assumptions of the models.

Schaefer (see, for example, Schaefer and Beverton, 1963) was the first to use a production model to develop management strategies for the yellowfin tuna fishery of the eastern tropical Pacific Ocean. The basic idea is that the rate of change of the population is

$$\frac{dP}{dt} = \phi(P) - fqP \qquad (2)$$

and equilibrium catch is clearly attained when $fqP$ is adjusted so that $fqP = \phi(P)$. If we let $\phi(P)$, as is customary, be a parabola, then we have in Pella and Tomlinson's (1969) notation $\phi(P) = HP^2 - KP = H\left(P^2 - \frac{K}{H}P\right)$ where $\frac{K}{2}$ is the maximum biomass. This may conveniently be plotted as a linear function $c/qf = K/H + (1/H)\,qf$ so that we have intercept $\frac{K}{H}$, and $\frac{1}{H}$ then is $\frac{d(c/qf)}{df}$ or rate at which the population declines per unit of fishing effort.

TABLE 2

Data used for yield-per-recruit calculations

| Age (Years) | Corr. Length | Corr. Weight | Inst. Growth Rate approximated from VBGF $L_\infty$ = 198, K = .28 | Inst. Natural Mort. |
|---|---|---|---|---|
| 0 | 0 | 0 | 1.2285 | 0.200 |
| 3.21 | 121 | 1 450 | 0.5319 | 0.208 |
| 3.68 | 131 | 1 862 | 0.4202 | 0.239 |
| 4.23 | 141 | 2 346 | 0.3309 | 0.239 |
| 4.88 | 151 | 2 910 | 0.2985 | 0.317 |
| 5.69 | 161 | 3 559 | 0.1774 | 0.492 |
| 6.76 | 171 | 4 302 | 0.1140 | 0.733 |
| 8.33 | 181 | 5 143 | 0.0571 | 1.138 |
| 11.29 | 191 | 6 090 | | |

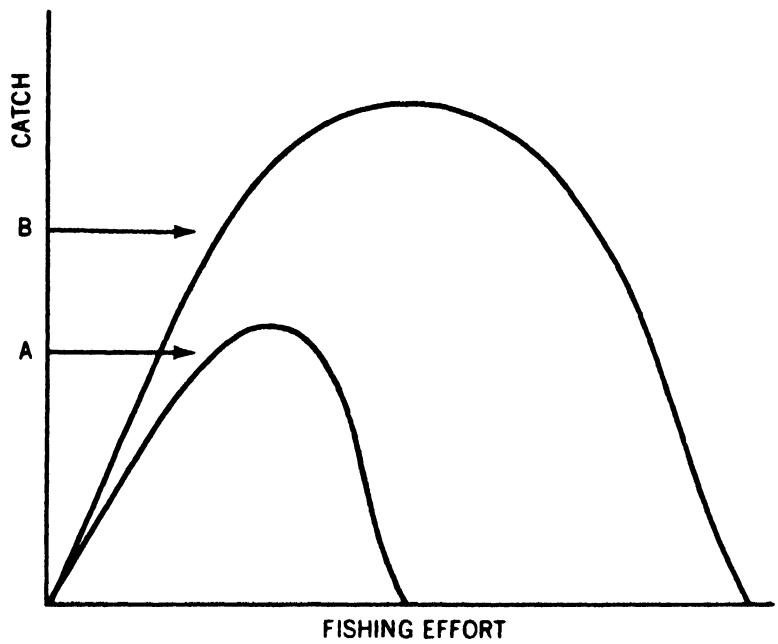



Figure 2. Relation between catch-effort curves when fishery expands from a smaller effective population (A) to a larger effective population (B).

The approach used by Schaefer was generalized by Pella and Tomlinson (1969) to yield, in general, a curvilinear relation between catch and catch-per-unit-of-effort and asymetrical relation between cat( and effort. Schaefer's approach is a special case of the Pella and Tomlinson presentation. Their generalization was obtained by letting $\dot{P} = HP^m - KP$. Fox (1970) examined the problem under more restricted circumstances. An interesting discussion of the behaviour of a stock as it approaches equilibrium may be found in Chapman et al. (1962). Equilibrium conditions can also be approximated as shown by Gulland (1969), by plotting catch-per-unit-of-effort against effort, using the average effort to which the fish has been exposed during its life in the fishery.

As indicated previously, the simplicity of the production model may be misleading. As an example, we need, explicitly, only catch and effort data. But implicitly we need to know, in addition, that effort is measured in units proportional to fishing mortality. Thus, in addition to information on fishing effort we also need to know that the catchability coefficient either is not changing, or if it is changing, then we need to know the nature of the change. Although the problem of the proportiona relation between nominal fishing effort and fishing mortality has been the subject of various symposia (e.g., see Gulland,1964), it is not clear that this problem is generally recognised by practitioners who use the general production approach.

To emphasise this point we repeat that a fundamental assumption in these methods is that the relation between nominal effort and catchability be constant over the series of data on hand. Basicall c/f is used in a production model to provide an index to the number of fish per unit area. In order for a set of c/f indices to accurately reflect the magnitude of the change in the number of fish per unit of area, it is necessary that f be measured in the same way for each c/f datum. This can be stated more precisely (following Gulland, 1969a) by noting that the instantaneous rate of fishing mortality in the $i^{th}$ year is equivalent to $F_i = f_i \left(\frac{q}{A_t}\right)$. We conventionally assume that the term in brackets is a constant for all i, and redefine the bracketed term as q' so that $F_i = q'f_i$. Thus it is implicit that q, A, and t must all be constant for each $f_i$; if q, A, and t are not constant then changa in $c_i/f_i$ may not adequately reflect changes in the population and the employment of such $c_i/f_i$'s in a production model may then generate management suggestions which could be quite costly in either a real or opportunity sense.

While some changes in catchability are rather obvious, resulting from direct changes in gear such as that which occurred when the eastern tropical Pacific yellowfin-skipjack tuna fishing switched from bait-boat to purse-seine gear, others may be more subtle in the sense that changes in the method of fishing resulting in changes in catchability may be difficult to either record or detect. Consider one possibility as an example: It is well known that the typical tuna longline bait is the saury. The Japanese-Russian catches of saury were quite large in the mid 1960's. These catches have, however, declined rapidly. It is unlikely, at the same time, that the average size of the saury in the catch has declined. There are also reports of increasedincidence of substitute baits. It is thus quite likely, owing to the decline in the saury stocks and events related to the decline that catchability in the longline fishery has been modified. The importance of this modification, if it has in fact occurred, again depends on the magnitude of the modification and the circumstances.

But even without direct modifications to the gear, changes in the catchability can arise in what are perhaps more subtle ways, especially in the context of general production models, by the fishery changing its areal distribution.

Let us consider several examples. First, if the fishery area increases (a situation which commonly occurs in tuna fisheries as perhaps typified by the expansion of the Japanese tuna longline fishing in the Pacific Ocean (Rothschild and Uchida,1968)) and the population size remains constant, then the catchability q' will decline. On the other extreme, if the fish are relatively immobile then as the area increases the effective population size could increase, but catchability might or might not change. We might view what might happen under the situation where the effective population increased but catchability and the other parameters remained constant. This is plotted in Figure 2. Curve A represents the catch-effort relation for the "old" fishing area and curve B represents the catch-effort relation for the old plus new fishing area where the individual fish tend to be relatively immobile. It would not be unreasonable, for a first approximation, to consider that the increase in the maximum size of the total population is proportional to the increase in the fishing area. It is also quite possible for catchability to change directly as the area of fishing changes. For example, contrast the previous example where catchability remained constant, but as the fishery expanded the effective "population" increased by virtue of the relative immobility of the fish with a situation where the fish may be relatively mobile but exist in a gradient of fish density. As the fishery moved into higher and higher densities the catchability would then increase. Actually both types of mechanisms are likely to operate as the fishery changes its areal extent. Even if it were possible to sort out the effects of increasing population size from changes in catchability it would be difficult to assume, for example, that the progression of the fishery would not eliminate the density

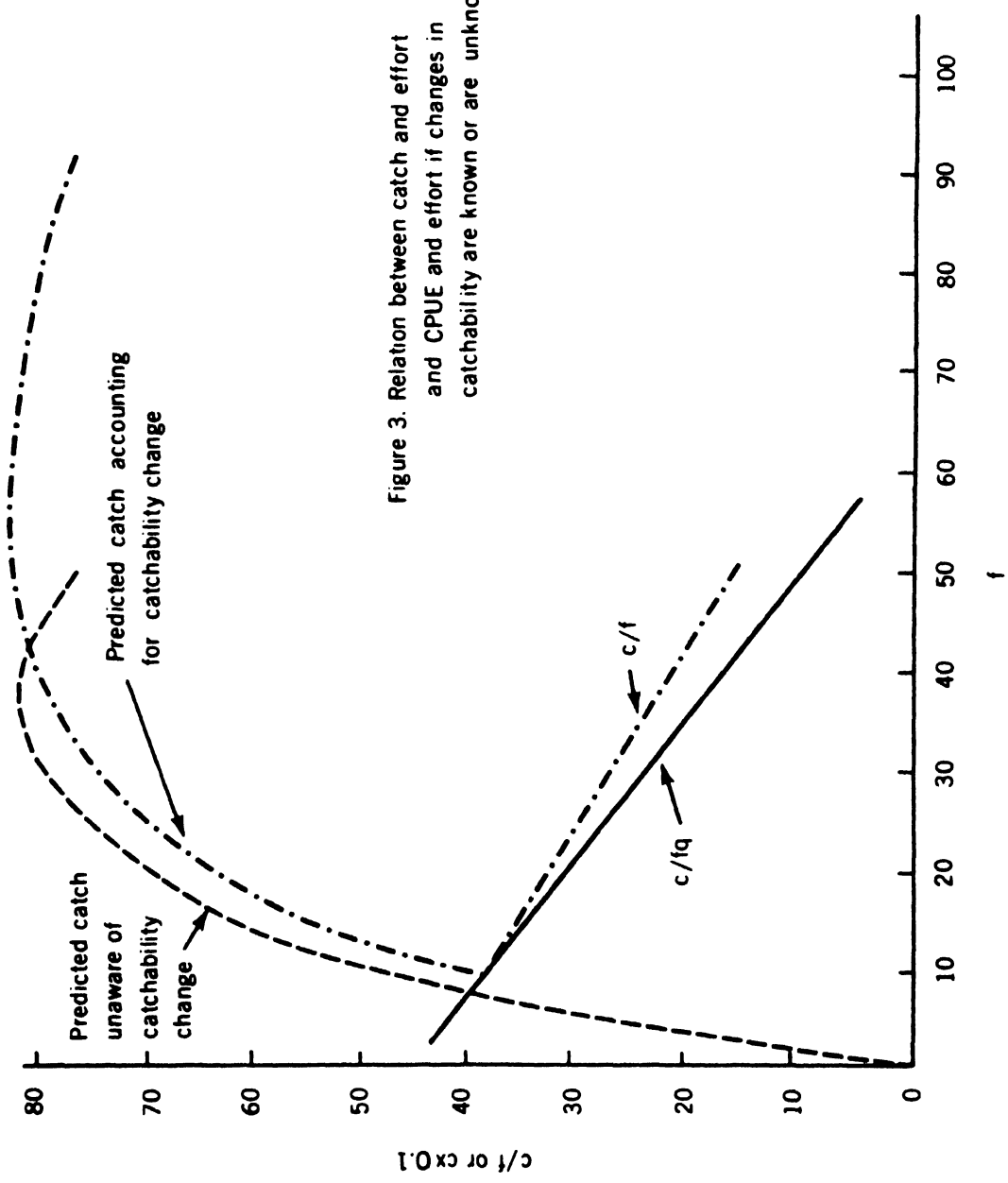



Figure 3. Relation between catch and effort and CPUE and effort if changes in catchability are known or are unknown

gradient and catchability would return to its original level.

These difficulties can be expressed more analytically by considering the old fishing region to have an area A and the new region to have an area a. The catches from these regions are related by the known constant k, using the usual notation,

$$F_A N_A = kF_a N_a \qquad (3)$$

so if we let q be the catchability in A and p the catchability in a, we can write,

$$qf_A N_A = kpf_a N_a \qquad (4)$$

Thus,

$$\frac{p}{q} = \frac{f_A N_A}{kf_a N_a} \qquad (5)$$

We have, however, a problem of identifiability, so taking one option if we wish to assume $N_A/N_a = A/a$, we can estimate p/q by plotting $kf_a N_a$ against $f_A N_A$ which should yield, if p/q is constant, a straight line passing through the origin with slope p/q. On the other hand we could assume p/q to be 1 and estimate the relative densities which are, of course, just k.

Thus, it is clear that we need additional information to understand the relation between p, q, $N_A$ and $N_a$. This information might be obtained from a tagging experiment and would lead to discerning whether a model accounting for increased population size would be appropriate or, on the other hand, increased catchability.

We have already pointed out the consequences of increasing the effective population size in the general production setting and it will now be useful to examine the consequences of increasing catchability. Catchability can be modified in a number of ways. Perhaps the most typical modification is an increasing trend in catchability. Such an increasing trend can be important. If this trend is unidentified a fishery could behave in an inexplicable way. In order to demonstrate this problem we have constructed a hypothetical set of data in Table 3. In the table we present, for reference, a set of data for which catchability is constant. We then modify the catchability by arbitrarily increasing its value as effort increases(strictly speaking, catchability reflects the relation between fishing effort and the number of fish in the population whereas production models usually relate the weight of fish in the population to effort.) We view these data in which the catchability increases with effort in two ways. In the first, we take into account the change in catchability and in the second we can pretend that we did not know that catchability increased. We are interested in comparing the conclusions from the two models. We have plotted these in Figure 3. The figure shows that c/f uncorrected for a change in catchability will underestimate the affect of fishing upon the population. We can also see that where the true c/fq will yield a symmetrical relation between catch and effort, the uncorrected data will yield an asymmetrical catch-effort curve. Thus, the degree of symmetry or asymmetry might relate to an inability to properly measure effort and not reflect any intrinsic property of the population which might be implied by fitting a general production type of model. The relation between catch on the correct and on the incorrect effort scale is also shown in the figure. We can see that if we do not recognise that catchability is changing we will at relatively low levels of effort obtain catches that are less than predicted, but at relatively high levels of effort we will obtain a catch greater than that which is predicted. The way in which we modified catchability was, of course, arbitrary, and so we can see that undetected modifications in q could greatly affect the relation between normal effort and catch and in some management situations the magnitude of this error might be important.

It is, in this connexion, of further interest to pursue a simple implication of the symmetrical yield-effort curve which is implied by a linear relation between CPUE and f. This relation was used in another context in our "Report of the meeting of a group of experts on tuna stock assessment (Under the FAO expert panel for the facilitation of tuna research)" which was held in Miami in August 1968. The implication derives from observing, in the usual notation, that

$$C = \frac{fq}{fq + M} R \qquad (6)$$

TABLE 3

**Hypothetical data showing the relationship between effort and expected catch when catchability is constant and when catchability increases with effort**

| Catchability constant | | | | Catchability increasing | | | |
|---|---|---|---|---|---|---|---|
| f | q | c | c/fq | q | nominal c/f | catch | f=fq |
| 10 | 1 | 380 | 38 | 1.0 | 38 | 380 | 10 |
| 20 | 1 | 610 | 30.5 | 1.033 | 31.5 | 630 | 20.66 |
| 30 | 1 | 690 | 23 | 1.130 | 26 | 780 | 33.9 |
| 40 | 1 | 624 | 15.6 | 1.282 | 20 | 800 | 51.3 |
| 50 | 1 | 400 | 8 | 1.875 | 15 | 750 | 93.75 |

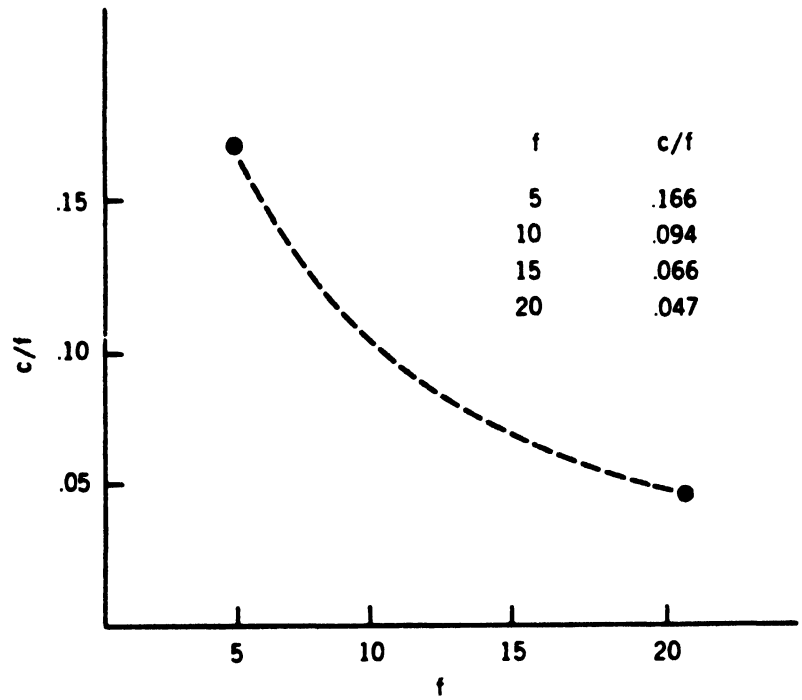



Figure 4. Relation between CPUE and effort when R, q, and M are constant.

from which we obtain

$$\frac{f}{c} = \frac{1}{R} f + \frac{M}{Rq} \qquad (7)$$

Thus if we plot f/c against f, we should, if R, q and M are constant, have a straight line with intercept M/Rq and slope 1/R. These are of course the usual steady state conditions. But now, in the context of our discussion, it is of interest to determine with these conditions of constant R, q and M the implications of plotting c/f upon effort with R, q and M constant. We can obtain from either (6) or (7)

$$\frac{c}{f} = R \frac{q}{fq + M} \qquad (8)$$

which we can immediately see is not linear by taking the derivative of the right hand side. So if we take some simple values of f, and set R = q = M = 1 and plot c/f as a function of f we have a curvilinear relation plotted in Figure 4. Thus for those situations where a plot of CPUE on f is linear, q, M and R are not, in general, all constant which may contradict some of the fundamental assumptions of the production models.

Thus we can see that two factors are generally quite important to utilising production models for management purposes: the possibility of undetected, but more obvious changes in catchability and the less obvious changes in the effective population and the mobility of the fleet vis-à-vis the fish.

While the fact that catchability changes is obvious, it is often not quite so obvious how it changes. One technique that might be useful was developed by Rothschild and Robson (MS) and is based on the concentration index which was suggested by Gulland (1955) and used in tuna work by Calkins (1963). The index, which is the ratio of the ratio of averages CPUE to the average of ratios CPUE statistic. This index has the unfortunate properties of (1) being difficult to interpret, (2) does not contain all of the information in the data, (3) is asymmetrical and has no upper bound. When the index is greater than 1 the fishermen are "concentrating on the fish", less than 1, they are not concentrating on the fish, and equal to the fish, fishermen distribution is random. Rothschild and Robson noted that since

$$\left[\frac{\frac{1}{n}\Sigma c}{\frac{1}{n}\Sigma f}\right]\left[\frac{1}{n}\Sigma\frac{c}{f}^{-1}\right] = 1 - E(c) - E(c/f)E(f) = 0 \qquad (9)$$

the correlation coefficient between CPUE and effort might be a better alternative index since the correlation coefficient is symmetrical about zero, is bounded between -1 and +1, might be interpreted probabilistically, and is easily interpretable.

Another technique that might be of some use in discerning the relation of the distribution of fish relative to that of effort and catch was used by Rothschild and Yong (1970) in their study of albacore distribution in the Northwest Pacific. They considered the spatial moments of catch-per-unit-of-effort, catch, and effort. It is clear that the distance between the first moments of CPUE and E, for example are a measure of the efficiency of the fleet and any temporal change in this statistic reflects a difference in operation that could produce changes in the catchability coefficient.

Another problem that could result in differences between observed catches and expected catches in a production model is that production models give the expected catches in terms of populations that are in equilibrium. Insofar as data from populations are essentially in equilibrium might be used to predict catches for populations in disequilibrium, and data from populations in disequilibrium might be used to predict catches from populations in equilibrium, errors could be induced in providing management advice. Perhaps the most important cause for disequilibrium in a fishery is the occurrence of strong year classes. Thus errors will be induced if data "in equilibrium" are used to estimate "equilibrium catch" for time intervals when there are no strong year classes.

A critical problem could arise if catches are greater than predicted owing to strong year classes, then there would be an inevitable clamour to increase the amount of fishing effort which might be undertaken by the construction of new vessels. The strong year class would, however, disappear from the fishery and the fishing operation would be in danger of over-capitalisation.

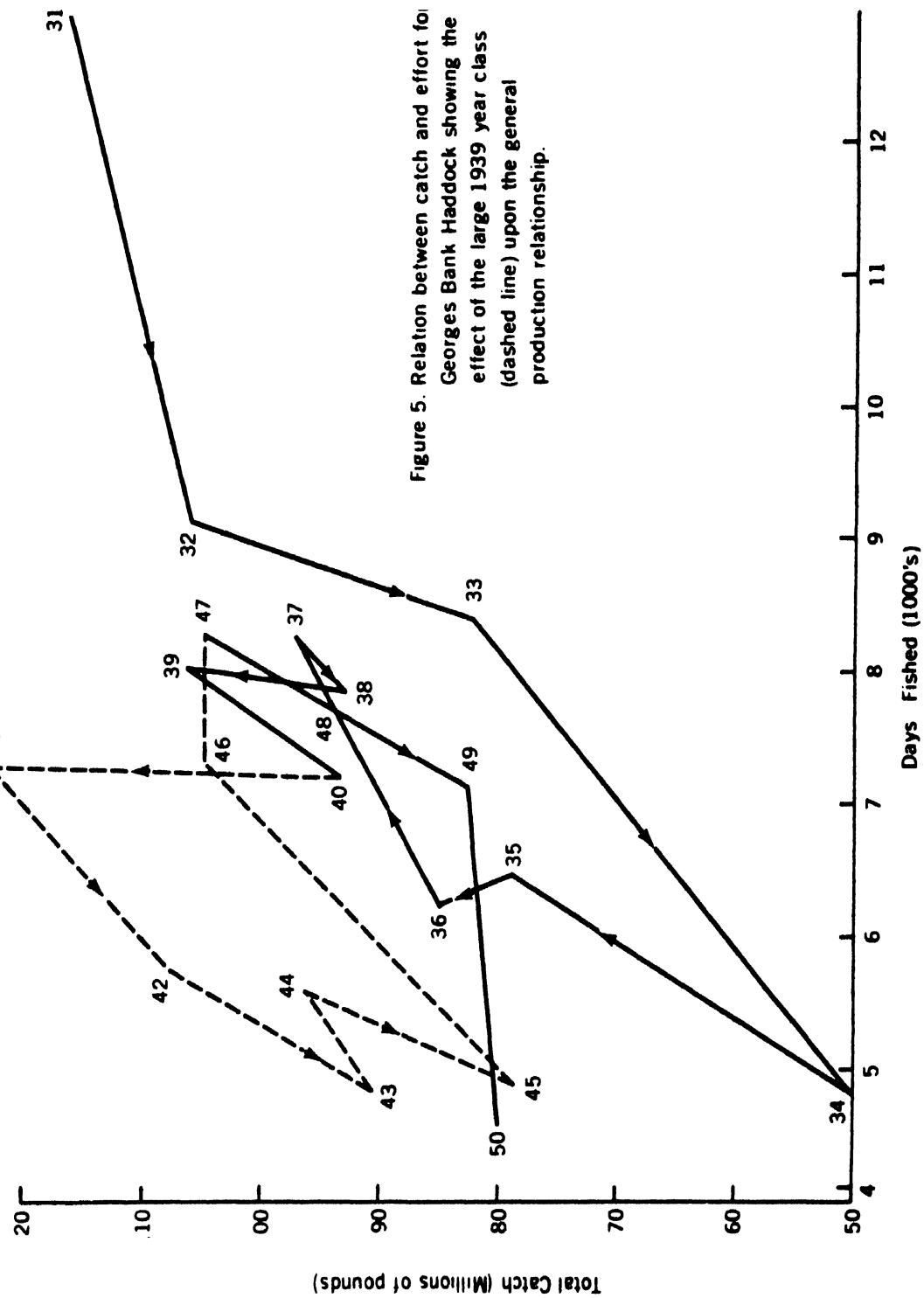



Figure 5. Relation between catch and effort fo
Georges Bank Haddock showing the
effect of the large 1939 year class
(dashed line) upon the general
production relationship.

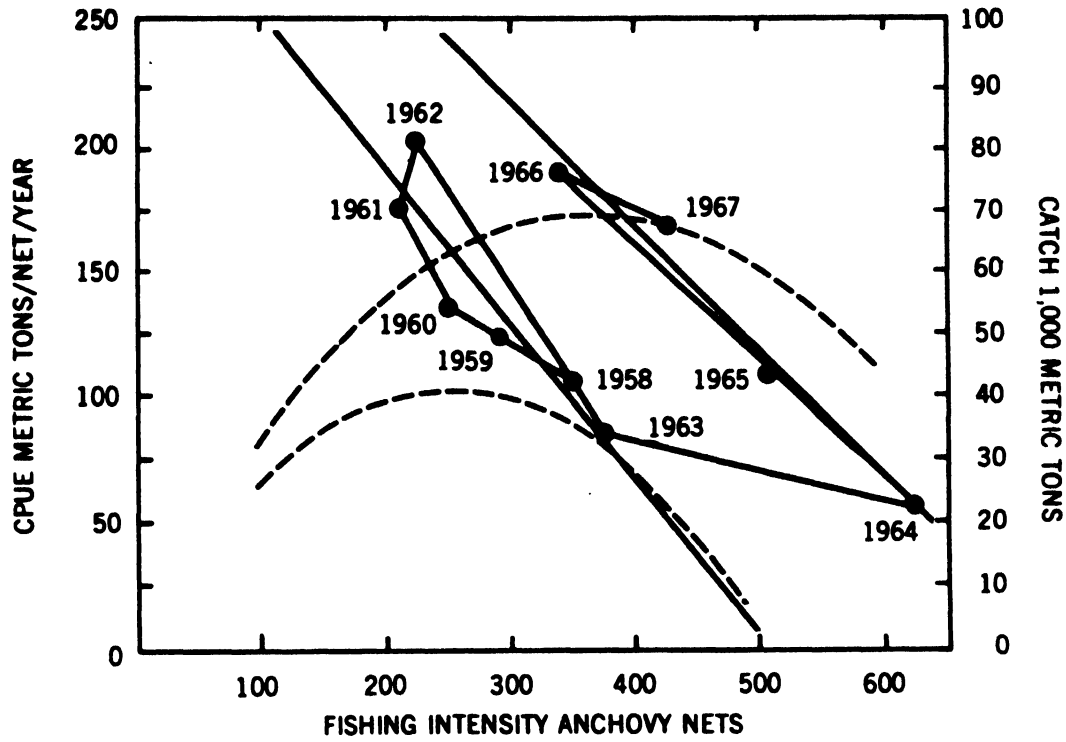



Figure 6. Regression of CPUE on fishing intensity and the total catch on fishing intensity for the anchovy in Korean waters.

To illustrate how this effect might operate, I will utilize the catch and effort data on Georges Bank haddock, which were presented by Royce and Schuck (1954) Table 4. These data include effort and catch statistics by age group for the years 1931 to 1950 and demonstrate the presence of the large 1939 year class which was evident in the fishery from 1940 to 1948. I have plotted these data in Figure 5. It is not necessary to fit an equilibrium yield curve to these data to see if we were unaware of the existence of the large year class and fit a curve to all of the data we would arrive at a different catch-effort relation than if we excluded the large year class from our computations. The presence of an undetected large year class might lead us to expect, depending upon the degree to which we are in an area of the curve which is extrapolated, to err, possibly seriously, in estimating yield from a given effort.

This example was chosen to demonstrate the effect of abundant year classes on the production model where it is known that these abundant year classes actually do exist. For most tunas age data or year class data would not be available. This would be particularly true for the more tropical tunas, but for these relatively short-lived fishes the effect would not be as great as that for the haddock which remain in a fishery for several years. On the other hand, the more temperate albacore and bluefin could be in a fishery for several years; there is some reasonable possibility, however, that the more temperature tunas can be aged.

Other subtle effects can contribute to misinterpretations of production curves. For example, change in gear selectivity can contribute to changes in age structure in the population and consequently to changes in equilibrium yield. This is easy to see intuitively because in the conventional yield-per-recruit model, we can alter yield-per-recruit by modifying the size-at-first entry. A possible example of such a situation may be evident in the anchovy stocks taken in Korean waters (Marr and Rothschild, MS).

This is shown in Figure 6 where we have regressed CPUE on effort measured in terms of standard anchovy nets before 1963 when the fishery was prosecuted predominantly by power drags which took large numbers of quite small fish and after 1963 when the fishery was prosecuted predominantly by gill nets which took larger fish than the power drags.

We can see then that the accuracy of production models in fisheries dpends upon the relation of nominal effort to true effort and again we will not belabour this point because it is covered in considerable detail in Gulland (1964) and other places. The question of whether errors in effort calibration affect accuracy seriously really depends, however, upon the use for which the data are intended. If the data are actually used in management then the questions we are discussing are quite important and measurable in either the value of the fish which are not taken and could be taken because of "under-fishing"; by the fish which are lost to the catch by "over-fishing"; or in terms of the additional effort required to take a fixed catch under conditions of "over-fishing".

Thus in some circumstances the measurement of catchability might be exceedingly important and it is useful to have estimates of f which do not depend on nominal effort. These can be obtained in a variety of ways such as using Murphy's (1965) iterative solution of the catch equation, use of virtual populations, or by tagging studies. Both the virtual population and iterative solution of the catch equation methods were used by Davidoff (1969) to study the yellowfin tuna in the eastern tropical Pacific.

Each of these methods has certain drawbacks. The tagging procedure is expensive and involves difficulties such as tag loss, but again the expense must be judged relative to the value of the information that would accrue if alternative approaches were attempted. Instead of using a recovery per unit of effort type of approach which would require estimation of effort we might use, for example, the Seber-Jolly (see, e.g. Seber, 1962) which would give us the probability of capture from fishing. The conversion of these probabilities to instantaneous rates is available in some of the demographic literature but not in fisheries literature. The method of deriving these conversions is outlined in Rothschild (1967).

The procedures involved in using either the iterative solution of the catch equation or the virtual population methods tax most tuna data since again it is difficult to obtain the catch in numbers of each age class. The iterative solution of the catch equation has been generalized by Tomlinson (1970) who has discussed the problem of bias in the method. It would be interesting to introduce an error structure in this method and study its behaviour using Monte Carlo techniques. The virtual population approach has been discussed by Fry (1949), Ricker, Bishop and others. The idea is that fishing must account for a large proportion of total mortality, because if this is true, the approximation

$$E \tilde{=} 1 - e^{-z} \qquad (10)$$

will be reasonable and since fishing accounts for a large proportion of total mortality, the further approximation $z \tilde{=} F$ should also be reasonable so from this we deduce

$$F \tilde{=} -\log (1 - E) = F' \qquad (11)$$

Owing to the nature of the approximation $F' \geq F$. If we can assume that $F'$ is proportional to $F$, then at least the relative changes in catchability could be deduced which would enable standardising effort to a standard year. Again, the estimation of catchability is a difficult problem using the available techniques. We can see that the available techniques for estimating catchability leave something to be desired, especially for those fish which are as difficult to age as the tunas. It would seem that another approach might be more applicable and this approach would involve an analytic study of fish behaviour and fish-gear interaction to construct a model which would predict the fraction of a population taken by a particular unit of effort deployed in a particular way. In other words, catchability would be estimated almost immediately by knowing how the gear is deployed rather than by hindsight, waiting for several years of data to accumulate. As an example of the very simplest use of such a method consider, in reverse, the "swept-area" approach for estimating population size.

The final existing management concept that we shall briefly discuss is the stock-recruitment problem, a problem which has been a serious occupation of fishery biologists, and subject of a symposium in Aarhus in August 1970. First of all, the stock-recruitment problem is usually attacked by plotting some index of stock size against some index of recruitment. The result is usually a cloud of points exhibiting little correlation. Then one of the usual stock-recruitment relationships is fitted to these data. It may be of scientific interest to continue to plot these relationships ad infinitum, but if we were to take the systems view we would make two observations. First, we would say that the stock-recruitment problem is overdetermined and not well defined. That is, the stock-recruitment system consists of many sub-systems which have not even been defined. These sub-systems consist of components that involve the behaviour and physiology of the larvae (possibly the adults as well) and while there is not a voluminous literature on this subject, there is a large amount of material, that, as far as I am aware, has not been brought directly to bear on the relation of stock and recruitment to predicting the abundance of year classes. Secondly, we ask what is the function(s) of studying stock and recruitment and how do the studies fulfil these functions. The function is obvious but it is questionable whether present techniques can be helpful. It appears to me that this is specially so in the tunas. The existent approaches at the strategic level, then tend to concentrate on using yield-per-recruit, general production, and stock and recruitment techniques. It is clear that a broader view of the strategic problem should directly acknowledge the problem of allocating multiple stocks to multination fisheries and that the several nations will need to consider strategies for allocating these stocks to the firm or firms which comprise their fisheries. There have been several schemes which have been proposed from time to time which suggest various allocation policies involving licensing and other techniques, but if we take the systems view of these we might say that these techniques provide solutions for problems which have not been sufficiently defined, and as a consequence these solutions might suggest policies which are not consonant with the higher level goals of the system. This is true for the tunas and in order to arrive at a non-intuitive policy we need to, at least, first define the system in terms of (1) its inputs and outputs, (2) the overall goals of the system, (3) the measures of performance, (4) the system environment (that is the components which are not modifiable by the system), (5) the system resources (the components which are modifiable and utilisable within the system) and (6) lastly the management of the system. We must then think of alternative systems and determine whether these alternatives are better than the existent system.

We can then see that our strategies essentially involve, as pointed out previously, adjusting effort and size at recruitment to some optimal levels which in practice, usually does not involve important problems of mixed-species fisheries; a stock or a collection of stocks fished by several countries, or economic problems. Because of this situation we have no guidance for the situation where, for example, one stock is exploited, depleted to some level, then abandoned for another stock. It is clear that the possibility for strategic management in fisheries (that is the technological tools) far exceeds our software and capabilities for management of these stocks.

In contrast to the wealth of specialized advice that is available for managing fisheries at the strategic level, there is virtually no information on the tactical or operational aspects of fishing. We can for the sake of discussion view one tactical problem as the allocation of a fleet to fishing grounds and an operational problem as perhaps day-to-day guidance on fishing vessel strategies. Again it is difficult to formulate specific solutions for general tactical or operational problems. We will, however, to demonstrate the feasibility of such an approach, apply the theory of dynamic programming.

TABLE 4

Catch, effort, and percent contribution of 1939 year class (by weight) for the Georges Bank haddock stock (after Royce and Schuck 1954)

| Year | Total catch millions of lb (rounded) | Days fished (000's) | Percent contribution of 1939 year class by weight |
|---|---|---|---|
| 1931 | 115 | 12.9 | - |
| 1932 | 105 | 9.1 | - |
| 1933 | 82 | 8.4 | - |
| 1934 | 50 | 4.8 | - |
| 1935 | 79 | 6.4 | - |
| 1936 | 84 | 6.2 | - |
| 1937 | 96 | 8.2 | - |
| 1938 | 92 | 7.8 | - |
| 1939 | 105 | 8.0 | - |
| 1940 | 93 | 7.2 | 2.3 |
| 1941 | 122 | 7.3 | 29.5 |
| 1942 | 107 | 5.7 | 33.8 |
| 1943 | 90 | 4.8 | 25.7 |
| 1944 | 96 | 5.6 | 21.4 |
| 1945 | 78 | 4.8 | 13.5 |
| 1946 | 104 | 7.3 | 9.2 |
| 1947 | 105 | 8.2 | 4.1 |
| 1948 | 94 | 7.7 | 2.6 |
| 1949 | 82 | 7.1 | - |
| 1950 | 81 | 5.7 | - |

There are many possible strategies that can be used on a tactical or operational level. For example, we may want to provide guidance on the route of a fishing vessel. Let us construct a simple dynamic programming example of optimising the route of a fishing vessel. Suppose we have a vessel capable of fishing for 3 days. The fishing grounds and the expected daily catch on each are as follows:

| Port | Fishing Ground I | Fishing Ground II | Fishing Ground III | Fishing Ground IV |
|---|---|---|---|---|
| | Expected catch = 2 units | Expected catch = 4 units | Expected catch = 3 units | Expected catch = 7 units |

Let us assume that if we are in any fishing ground on any day and remain in that fishing ground on the next day then we can catch, on the next day, the full expected catch. If, however, we decide to move to another ground we must pay a penalty in lost fishing time. In order to keep the arithmetic simple we reduce the catch by one unit for moves of +1 or −1; 2 units for moves of ±2, moves > ±2 reduce the catch to zero. Thus on the first day transitions between port and each of the four areas would yield the following catches:

| From \ To | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Port | 2 | 3 | 0 | 0 |

on the second and third day we would have catches as follows:

| From \ To | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 2 | 3 | 1 | 0 |
| 2 | 1 | 4 | 2 | 5 |
| 3 | 0 | 3 | 3 | 6 |
| 4 | 0 | 2 | 2 | 7 |

and on the final day we pay the following penalties which are related to our distance from port at the completion of the fishing trip.

| From \ To | Port |
|---|---|
| 1 | 0 |
| 2 | −1 |
| 3 | −2 |
| 4 | −4 |

Given these data we can use the dynamic programming algorithm to find the route which will maximize catch. We begin with the last day and work toward the first. The consequences, with respect to the model, of being in any location on the fourth day are in the above table. The catches, adjusted for penalties on the third day, are based on our decision on the fourth day and are as follows:

| From \ To | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 2 - 0 = 2 | 3 - 1 = 2 | 1 - 2 = -1 | 0 - 4 = -4 * |
| 2 | 1 - 0 = 1 | 4 - 1 = 3 | 2 - 2 = 0 | 5 - 4 = 1 |
| 3 | 0 - 0 = 0 | 3 - 1 = 2 | 3 - 2 = 1 | 6 - 4 = 2 |
| 4 | 0 - 0 = 0 | 2 - 1 = 1 | 2 - 2 = 0 | 7 - 4 = 3 |

*(Catch on third day if we transit from 1 to 4) - (penalty for being in 4 on last day) = (cumulative catch for 1 → 4 → port route)

Pursuing the above table shows that cumulative catch that we would expect if we were in a particular location and chose another location for the next day of fishing. We can then determine from the catch maximizing decision for any starting point from the table. These catch-maximizing decisions are as follows:

| From | Destination for maximum catch | Maximum catch |
|---|---|---|
| 1 | 1 or 2 | 2 |
| 2 | 2 | 3 |
| 3 | 3 or 4 | 2 |
| 4 | 4 | 3 |

Now preceding to the next previous stage we add the maximum catches from the above decisions to the transitions for the preceding day obtaining the cumulative catches for the next previous stage, which are:

| From \ To | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 4 | 6 | 3 | 3 |
| 2 | 3 | 7 | 4 | 8 |
| 3 | 0 | 7 | 5 | 9 |
| 4 | 0 | 5 | 4 | 10 |

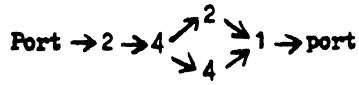
and these yield the following catch maximising decisions:

| From | Destination for maximum catch | Maximum catch |
|---|---|---|
| 1 | 2 | 6 |
| 2 | 4 | 8 |
| 3 | 4 | 9 |
| 4 | 4 | 10 |

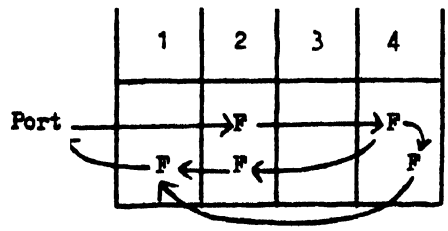
We then apply these to returning to port obtaining the initial optimal decision:

| From \ To | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Port | 8 | 11 | 9 | 10 |

and we can see here that the optimal decision is location 2 and yields an expected cumulative catch of 11 units. So the optimal path(s) which maximize catch less travel penalties is




The vessel track would be




We can see then that there is a rather large opportunity to consider strategic, tactical and operational views of a fishing system. There is an interesting aspect of this opportunity and this reflects from the iterative nature of systems analysis which states that we might wish to reformulate our problem after we have examined it from a systems viewpoint. Our reformulations, in this case, would be to modify what we customarily consider to be a strategic view of fisheries in light of the possibility that in managing fisheries as a total system, we might wish to include, in our concepts, the tactical and operational view as well.

It is apparent that, as we increase the complexity of our concept of management, we will need to formulate an information system so that we can have flexibility in making management (in the broad sense) decisions and formulating policies. As a beginning we can consider applying modifications of the management information concept forwarded by Blumenthal (1969).

We begin by constructing a fishery "environment" in which, following Blumenthal's use of Forrester's terminology, there exists a series of "levels". The levels reflect the present value of stock size, species composition, fleet position, inventory at sea, inventory on shore, etc. Each level is a black box which contains a data capture device which transmits data from the environment (see Figure 7) to the various management systems (Figure 8). We make no distinction at this point between nature's

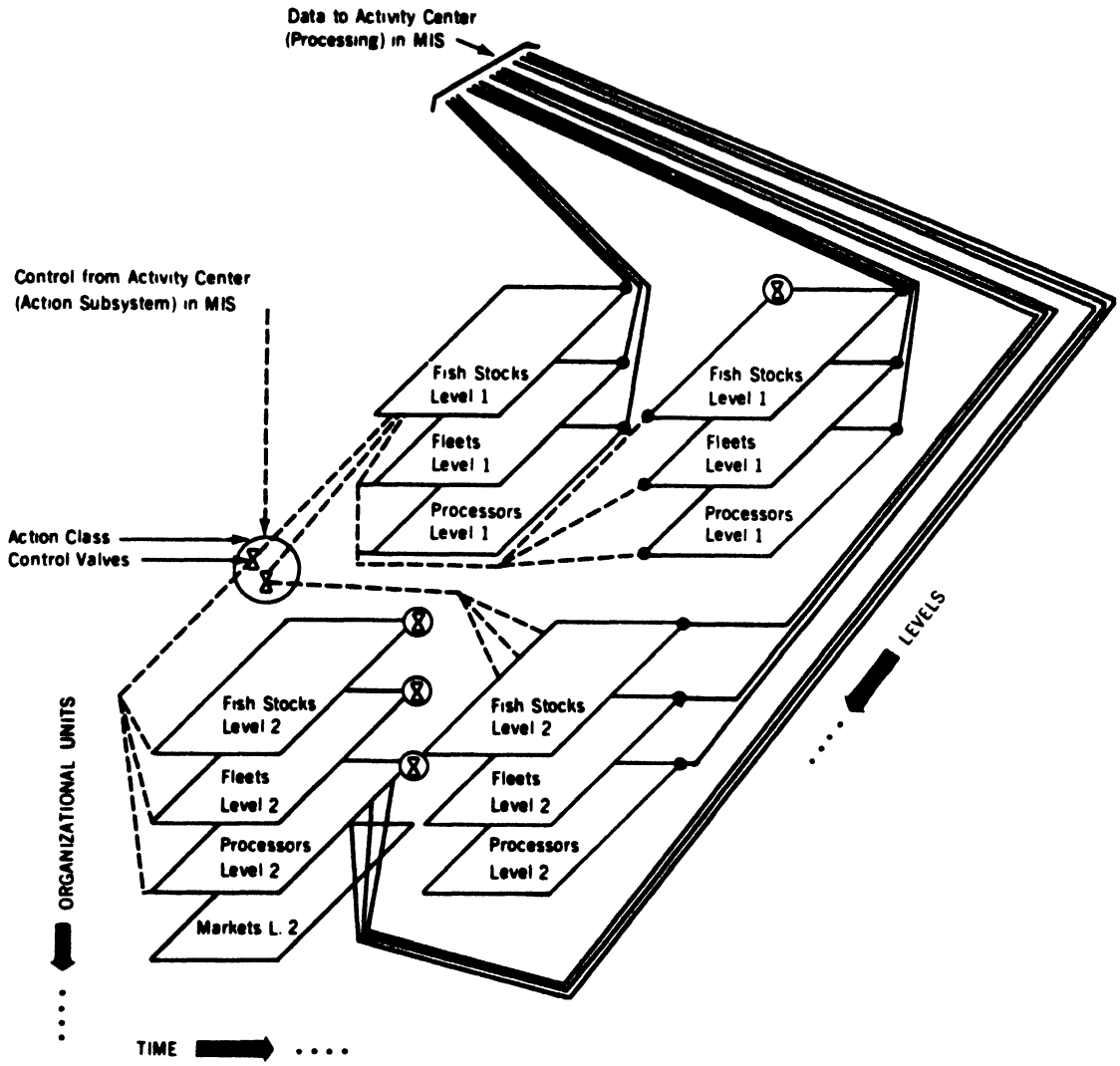



Figure 7. Skeleton of the fishery environment and its interfaces with the management information system

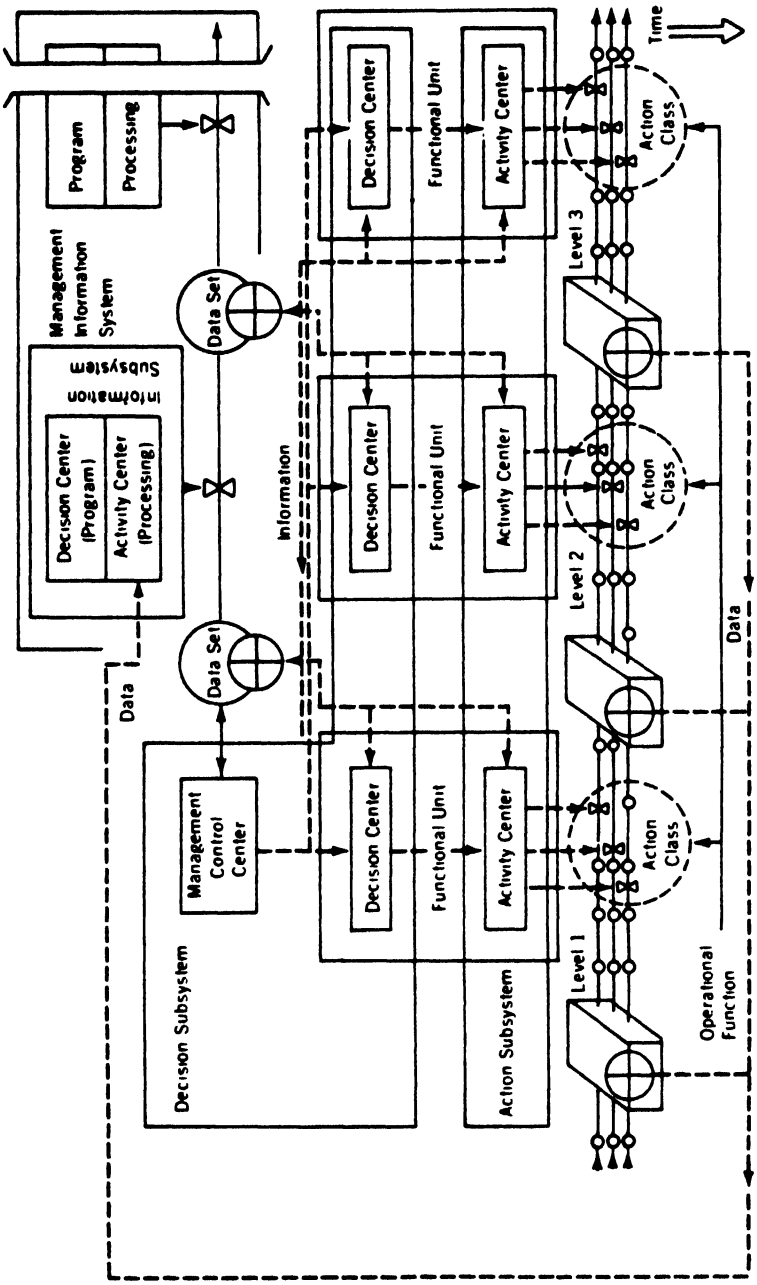



Figure 8 Management information system as outlined by Blumenthal (1969)

management and man's management. In terms of nature's management there is of course, hopefully, a considerably greater degree of ambiguity and equivocation in the actions which are communicated and the data which are transmitted. Generally speaking, pertinent wires in each cable control the rate of flow between the levels and again control is not necessarily deterministic. The rates of flow in each cable are generally controlled by an activity centre which is guided in a functional unit by a decision centre. The decision centres are guided by a management control centre. The collection of activity centres constitute the action sub-system and the collection of decision centres plus the management control centre constitute the decision sub-system. The decision sub-system plus the action sub-system plus the environment essentially form the substrate for the management information system.

The utility of such an information system should be obvious. The applications can relate to the more sophisticated integrated system providing information to the fisherman and the processor or to the extant fishing operation or to segments of the extant operation. It is clear that, for example, there are no virtual real-time data available on the collective tuna fishing operations of the world. If we are to manage these fisheries, most of which involve several species and several fishing nations we will simply need to have timely data.

The important question that we face is the implementation of a systems-oriented approach to fisheries. One view is to take the so-called "total systems approach". A total systems approach to the tuna fishing problems of the world is not something that we can easily define without further detailed analysis and even if we could define a total systems approach for managing tuna fisheries, there would most likely be a time lag, perhaps considerable, before the fisheries could be integrated toward a unified systems concept. On the other hand, if we consider the proper utilization of our resources then we would be severely remiss if we did not acknowledge the complexities of the total system and try to solve them. I hasten to add that this does not mean, because there are, for example, economic problems related to the fisheries that we should emphasize the study of economics by itself. Rather, it does mean that the study of a particular fishery system and all conceivable fishery systems relevant to the particular fishery system should acknowledge the economic problems and incorporate the economic problems in a total view of the problem.

In this connection, it is pertinent to peruse the various reports of the FAO Expert panel for the facilitation of tuna research. This perusal might reflect a high degree of concern by tuna researchers of the world with various techniques and activities such as tuna taxonomy and tuna tagging. These are, in some, but not all contexts, useful techniques. If, however, we were to take a systems view we would instead concentrate upon the problems of tuna management and how to resolve them. We would in particular concentrate upon formulating the various problems in terms of their objectives, context, assumptions, criteria and hypotheses. We would search for necessary data, elucidate relationships, form necessary approximations, look at alternatives and identify costs. The various resulting alternatives would be constructed by the construction of models and these would be adjudged in terms of sensitivity analysis and cost-effectiveness. The system could then be interpreted in terms of contingencies and uncertainties.

Finally, we arrive at the actions that need to be taken to turn the systems view into action and these involve questions of the attitudes of the institutions involved in making decisions on the future of the fisheries. Whether the institutions can take a systems view depends upon the enlightment of administration and the influence extended by the community of individuals associated with the fishing industry (fishermen, scientists, and businessmen) and their ability to communicate these concepts to appropriate funding entities. This communication depends, of course, upon political considerations, but it also depends, rather heavily, upon being able to talk the language of the funding entities which are also taking systems views. In so doing many funding entities are emphasising programme budgeting. I have already outlined some of the philosophical problems associated with building a basis for programme budgeting (Rothschild and Uchida, 1968). In the administration of problems associated with programme budgeting there are several concepts which should be considered and I have outlined these elsewhere (Rothschild, 1967)

> Consideration of programmes should not be limited to fixed objectives, adjusting inputs and outputs to meet these. Rather, the objective should be considered as a variable and the several values of this variable should be considered among the alternatives.
>
> Budgeting should concentrate on allocation of activities rather than on being utilized as a tool of management.

Budgeting should not focus on functions, the individual's accomplishments to be achieved and the work to be done. These should be regarded as intermediary processes. Budgeting should concentrate on the aggregate of these intermediary processes.

Budgets should evaluate programmes rather than activities.

In budgeting the incremental-decremental approach should be avoided in favour of viewing alternative programmes.

In summary, then, I have attempted to consider the fundamental problems of tuna management. In so doing I have taken a systems approach. This approach suggests that the tuna fisheries of the world have not been described as systems and that, accordingly, there are no guidelines for how these important fisheries should be managed. The existing management concepts are mostly strategic, involving yield per recruit analysis, which we can make more complex than the data which are available to us; general production analysis which could require a rather delicate understanding of the way in which effort is measured, particularly in a fishery that is changing dynamically; and the use of stock and recruitment which is most likely of little use in managing tuna fisheries, at least with existing techniques. While these problems are certainly important, it would appear to me that the aforementioned problems of allocation are at the heart of conserving the tuna resources where, by "conserving", we mean that action whereby man makes the best use of the resource. While there have been various allocation schemes, such as leasing or licensing fishery shares, I do not believe that we have enough timely information about tuna catches, effort distribution, landed fish distribution, added values, etc., to actually understand the tuna "system" on a worldwide basis to adequately formulate the tuna problem as a systems problem and for this reason it would be unwise to propose particular allocation schemes for either the status quo situations or for future likely situations. It would therefore seem advisable to begin to define the tuna "system".

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